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Monthly by Reinhold Publishing n, 330 West 42nd St., New York ., U. S. A. Ralph Reinhold, Chair- Board; Philip H. Hubbard, Presi- Burton Lowe, Executive Vice Presi- Treasurer; G. E. Cochran, Vice and Secretary; William P. Winsor, ident; Francis M. Turner, Vice Price 50 cents a copy. Payable in one year, $4.00; two years, $6.00; rs, $8.00 in U. S. and Possessions, and Pan American Union. $2.00 each year in all other countries. New York Draft.) Copyright, 1947, old Publishing Corporation. Printed Press, Inc., 508 West 26th St., New N. Y. All rights reserved. Re- as second class matter Nov. 14, the Post Office of New York, nder the Act of March 3, 1879.

Materials & Methods

THE
METALWORKING
INDUSTRIES'
ENGINEERING
MAGAZINE

VOLUME 25, NO. 5 May, 1947

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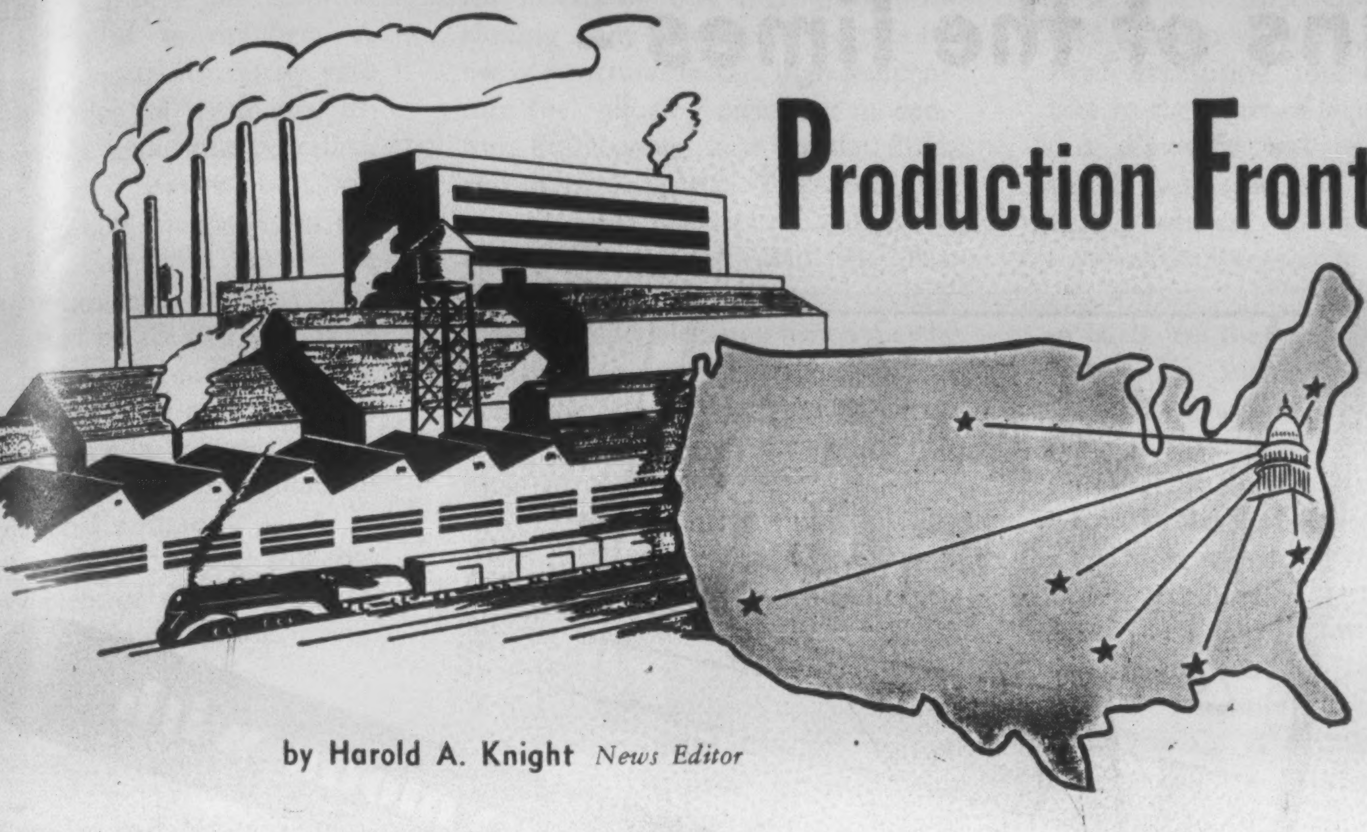

Production Frontiers

by **Harold A. Knight** *News Editor*

Public Opinion Emerges as Nation's Greatest Power

When the framers of our Constiution drew up their famous docunent and the builders of our governnent set up the machinery for our xecutive, legislative and judicial ranches, little did they realize how y the middle of the twentieth cenury, say, a fellow by the name of eorge Gallup would be the symbol f real power behind Washington fficialdom.

We learn from recent Gallup polls, or instance, that President Truman's opularity, which was at its lowest bb during the November elections, as by now risen to fairly dizzy eights. The public opinion poll is alpably a product of today, made ossible by rapid communications, vailability of the people because of utomobiles, good roads, airplanes nd streamlined trains.

Don't think for a minute that resident Truman and all other Washington bigwigs are oblivious to eorge Gallup and his host of padnd-pencil-in-hand interviewers. We enture to say that these public pinion polls have more influence n every day rulings and legislation propounded at Washington than any other single factor.

We would not be surprised if sometime in this century there would be a new Department of Public Opinion, the Secretary of this department being a member of the cabinet and always sitting at the immediate right of the President at all cabinet meetings.

In what other country can public opinion be so vocal as in the United States? Can one imagine a Gallup poll being conducted in Russia in the first place and/or having any influence in the Kremlin if it were allowed?

Our country has progressed far from those days of only two generations ago when "Public-be-damned" was the keynote of many big enterprises.

"No company today can hope to prosper if it does not concern itself, on the highest policy-making levels, with how the public reacts to its policies and decisions," recently stated William L. Batt, president, SKF Industries, Inc. "Management has learned the hard way that public approval must be as vigilantly pursued as a prospective customer. It is beginning to learn that public approval is gained only through continued confidence and trust in management's actions."

We recently heard Senator George W. Malone of Nevada make an informal talk. One of his statements that we jotted down in our notebook was: "Public opinion is more powerful than laws."

It will be P. O. that finally squelches once and for all such tinny little Czars as John L. Lewis. In fact, it is public opinion which made and keeps this nation great. Just as all machinery works faster than a half century ago, so does the machinery of public opinion work faster. The P. O. of yesterday is known at Washington today.

Public Opinion and Labor Legislation

The last time we were in the Capitol city we saw that public opinion was fashioning new labor legislation somewhat along these lines:—

An amendment to the Wagner Act is called for. There will be improvements in mediation machinery—probably set up outside the Department of Labor. This machinery will go to work when everything else has failed. Foremen will be allowed to organize—at least in the large com-

Signs of the Times -

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ies. There will be a limitation on ss picketing as to numbers. A w law will require a majority vote d secret ballot of employes inlved before a strike can be called. Under the new laws the boss will allowed to talk straight from the oulder to his employes, provided he es not intimidate. Industry-wide rgaining will be allowed as long as is not against the public interest. e Government will have the right use the injunction, to assert nation- sovereignty where the dispute enngers national welfare.

Acts of violence in strikes will conue a problem of the State police, t that of the Federal Government.

aterials Needed for Atomic Power

The Germans suffered a fiasco in veloping atomic energy and the omic bomb largely because the ientists did not call in engineers give a practical touch to their work. e German scientists regarded emical engineers as merely glorid pipe fitters. Many a time, doubtss, in German laboratories a delopment reached the stage where it uld be successfully engineered, but e German pure scientists did not alize this—and the engineers had t been consulted.

So stated P. C. Keith, president, ydrocarbon Research, Inc., who was tively connected with the engineerng of the atomic bomb and who poke at the 75th anniversary meetng of the American Institute of ining & Metallurgical Engineers.

At the same session on atomic nergy, H. A. Winne, vice president, eneral Electric Co., outlined the ature of some of the materials that ould be needed, many as yet undeeloped, to generate atomic power in e form of heat. Thus, the use of aterials in a nuclear chain reactor r "pile" involves consideration of heir "nuclear properties," whereas revious considerations involved only xternal physical and chemical proprties.

This portends many changes from e engineering materials which have ecome common. Thus, beryllium, a oderator because of low atomic eight, must be free of neutron aborbing impurities—but making such etallic beryllium is still almost a aboratory process.

There will be increasing demands for metals of very high purity, including many now considered rare for use as structural metals, high temperature fuel, alloying elements, moderators, liquid metal heat transfer fluids and radiation shields. The metallurgy of fissionable materials is a new and only partially investigated field. Possible alloys and mixtures include many metallic elements which may be valuable because of low absorption of neutrons. The fuel designer may wish to consider ceramics to obtain very high temperatures.

The selection of a fluid to carry the heat from the nuclear reactor to the heat exchanger in which it may be converted to steam or a hot gas is a vital matter. Gases, liquids and liquid metals must all be considered. The medium must have low neutron absorption. It must be reasonably stable under intense radiation. It must have good heat transfer characteristics, be non-corrosive, non-toxic, non-explosive, etc.

If the medium boils in the reactor neutron absorption characteristics of the vapor must be the same as the liquid, otherwise a sudden flashing to vapor of a part of the liquid might result in such a sudden change of nuclear characteristics in the pile that the control mechanism could not compensate for it.

If research can reduce the volume and weight of shield it will facilitate application of atomic power to ships and elsewhere.

Among the possible applications of nuclear fission are in metallurgy in the form of radioactive tracers. Diffusion of an element into itself and into alloys in which it is a component could be followed if the diffusing atoms are radioactive. Again, inclusions could be identified by adding a radioactive form of a suspected component to the melt and photographing by microradiographic techniques. Finally, positive identification and location of minor constituents, which often markedly affect the properties of metals and alloys, could be made by microradiographic methods; such information is usually very difficult to obtain by microscopic methods.

"Nothing New Under the Sun"

Even the most blasé in this world occasionally encounter what is really a new discovery—such as the pyramids in the heart of China, recently seen by an American aviator. We read in the newspapers, too, how the Byrd expedition found an ice-free lake in the heart of Antarctica. Even this discovery was apparently not strictly new, since the New Bedford, Mass., whaler, "Nathaniel Palter," surveyed this region in 1840, as did the Russian Admiral Bellinghausen in 1820. Yet the region had apparently been forgotten for over a century.

The best account we have seen of these warm water lakes appeared in the "Martin Star," house organ of the Glenn L. Martin Co., which made the aircraft in which Antarctica was recently explored. This warm water lake covers 400 square miles and is dotted with ice-free brown rocks, as islands, "resembling chocolate drops" from the air. After all, just another case of the near-surface hot water of Yellowstone Park in our own country, resulting in geysers and hot springs!

This geological furnace in the Antarctic is known as a "batholith." Though there is no vegetation, a few birds were found around the lake, an interesting variation from the ever-present formally-dressed penguin. Also discovered on this expedition were "ice volcanoes" that had belched up ice. They are gigantic bowls of ice with floors a mile in diameter, surrounded by ice walls 100 ft. high, the region looking like the pock-marked surface of the moon.

Here is the way Nature did the trick. Gas became trapped in the middle of the ice shelf, with pressures building up until explosions resulted, making craters and piling up ice blocks that had been blown out.

Some day, of course, valuable minerals and metals may be found in this region to augment rapidly depleting resources in this era of modern civilization. Again, air stations may be built there to facilitate long distance routes between foreign capitols over the South Pole.

Speaking of penguins, we believe that one of the most amusing anecdotes we ever heard involved one of the earlier Byrd expeditions. It seems that during the mating season the male penguin, after looking over the females and making his choice, grasps a pebble in his beak, toddles over to his glamour girl friend and deposits it at her feet. If she picks it up this signifies her acceptance of him as well as his pebble. If she ignores the pebble and donor—that's the run-around

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hat the male well understands. He akes his turn-down philosophically nd perhaps makes a second choice, till hoping.

It seems that one of Byrd's engieers was standing outside the huts in Little America" one day, thinking omewhat nostalgically of home. Along came a penguin and deposited pebble at his feet.

Touched to the quick by this sign f genuine affection, he picked up the ebble with a grandiose gesture, laced his hand on his heart and owed low and majestically to the enguin who had so honored him.

Recovery in Europe

As to the explosive and devastating effects of the Bikini atomic bomb s seen from a safe distance, conditions in devastated Europe, or what was observed in a flight around the world, we believe that our best accounts and most vivid impressions have been secured from trade journal editors.

Of course, we are prejudiced in favor of such an observer, but we honestly do believe they are best trained for such observation and telling thereof from long experience in accurate observation, correlation of facts and assembling of them in the spoken word and particularly the printed word.

Accordingly, we looked forward with anticipation to the recital by Erik Oberg, consulting editor, *Machinery,* of his trip to Europe, arranged by the War Department. We were not disappointed.

In Germany production of ball and taper roller bearings, all heavy machine tools and certain types of heavy tractors is forbidden. Maximum steel production is 5,800,000 tons yearly as against 26,000,000 tons in prewar. The only steel plants left are the older ones. Machine tool production will be 11.4% of the 1938 capacity. In heavy engineering 30% will be retained, in the heavy electrical industry, 30%, and in light electrical, 50%. They may build 40,000 passenger automobiles yearly against 275,000 before. No new locomotives may be built until 1949.

As to agricultural machinery, 80% production is allowed, along with 10,000 light farm tractors. About 230,000 tons of machinery will be shipped to victor countries in 1947. All ball bearings making equipment will be shipped to Russia and some Western powers. In the American zone only actual war production plants, of no peace use, are being destroyed.

Only 10% of bombed-out bridges have been replaced with permanent structures, others being of a temporary nature, necessitating slow train movements. Passenger train movement is greater than ever before, compensating for lack of automobiles, and with much transporting of displaced persons, expellees and refugees.

Coal for residence heating is allowed for only one room in a house, though in Hamburg no coal for residences has been available since October. Housing in Germany was reduced by 25 to 40% until 14 to 15 are sheltered in a seven-room house. Every means is being taken by our military government to promote German exports and make Germany self-supporting. Holland, Scandinavia, and nations of Southern Europe depend on many German products for their own economic life. For three to five years Germany will partly depend on the United States and England for her food; thereafter she can be self-supporting. A few hundred millions invested by us in Germany now may save billions later.

As to Austria, in many respects she has made faster advance towards an independent nation than Germany, though has not the natural resources of Germany. In the U. S. zone all damaged bridges have been rebuilt and railroad transportation is the best in occupied Europe, being 97% normal in the U. S. zone.

In Italy industrial production in 1946 was 65% of the 1938 volume and was double the preceding year. Of nearly 13,000 railroad and road bridges damaged, 1700 have been rebuilt and 3000 repaired.

Of all the Continental countries France has most nearly returned to normal conditions. [We have heard this repeatedly said about Belgium—Editor.] Except for the scarcity of coal during winter months, the French industries have practically recovered their prewar activity, especially in the machinery and machine tool industries. In fact, machine tool output is thrice the prewar. Owners of industrial plants deem it better to have capital in form of equipment than francs in the bank. Railroads have almost reached prewar efficiency. On main lines trains operate at same high speeds as in 1939.

Unofficial Observer Sees Russia

A good friend of ours recently returned from an extensive visit to major European countries. He was appalled at the squalor and hopelessness he encountered. Only Sweden, Switzerland, and to some extent Belgium, begin to live on the United States scale. We are not permitted to reveal the name of this gentleman—he might like to return to Russia some other time.

Speaking of Moscow and the Russians, he told us: The squares surrounding the Kremlin are gorgeous and impressive, but walk just a few blocks and one finds depressing poverty. The average Moscow resident lives four to a room, usually in unheated flats. Very rarely does one encounter a person as well dressed as the average American. Our friend was assigned "B" rations, a breakfast consisting of bread, cheese and piece of salami.

The "iron curtain" exists partly because of the difficulty to surmount language differences. There is only a thin veneer of engineers and professional men at the top of Russian society. There is a steep drop in intelligence, skill and professional knowledge to the next layer. His theory is that to be a technical or professional man takes a lot of courage. He is a conspicuous man and one bad mistake gets him punished, perhaps banished to Siberia, maybe killed. There is not much incentive for the tender-hearted, therefore, to try to attain the heights. Yes, the Russians turn out good automobiles, apparently comparing well for practical qualities with American cars. However, production of the leading maker is only one car per day.

The caste system is very apparent. Take a line-up at a restaurant. A well-dressed man appears. He immediately jumps the line and the headwaiter straightway conducts him to a table. Yet the Russians, artwise, are a very remarkable people. Their ballet, opera and drama are perhaps the most impressive in the world. The sullen, stoical Russian unlimbers in the theatre. There are smiles, laughter, relaxation and thunderous applause. Under such environment the Russian is a spontaneous, ebullient, blithesome individual, concludes our friend.

The MATERIALS OUTLOOK...

Hot-Rolled Sheets Scarcity

Stamping manufacturers and other users of hot-rolled sheets had better become resigned to scarcities for another year or two. They will be one of the hardest-to-get steel items until steel again becomes a buyers' market. About 18 months from now steel makers will again tumble over one another to cater to your wishes. Meanwhile, better buy cold rolled sheets, or maybe you can use aluminum, as others have done. There is more profit in cold-rolled sheets, and capacity has been expanded tremendously. Some sheet makers are abandoning hot sheet sales entirely. In January, hot-rolled sheet and strip shipments were 50.6% of total sheet and strip, which is encouraging, at least. Why not appeal, through your trade associations, to the steel makers? Offer them more cash for the hot-rolled so that it will be profitable for them to sell?

Zinc, Copper and Lead

Here's the way a veteran of the base nonferrous metals industry sizes up the future course of prices among three of the common metals. Prices may decline "sooner than you think" because of the great pressure from many directions towards lower prices. Zinc will be the first to yield, followed by copper and then lead. As we've said before, lead is a metal that seems definitely on the toboggan as far as world supplies are concerned. Peak world production came in 1939 as against 1942 or 1943 for most major metals. The world is definitely starved for lead—and will continue hungry for a long time, perhaps always.

Low Alloy, High Tensile Steel

You are going to find more inducements to use this steel. Manufacturers are pushing production and carrying on a campaign for wider applications, among the large tonnage newer possibilities being bridges and ships. With greater mass production will come lower prices. Promoting more widespread use, for instance, is cross licensing—Inland has licensed Carnegie-Illinois to make "Hi-Steel," while Carnegie has licensed Inland to manufacture "Cor-Ten." Republic and Carnegie-Illinois also have cross-licensing agreements. Three tons of low-alloy steel will replace four or more tons of ordinary carbon steel. This general type of steel is easily fabricated, too. For bridges and ships these steels are corrosion-resistant.

Rubber Prices to Cheapen

Rubber consumers will use up about 1,000,000 long tons of rubber in 1947, which will be about equally divided between natural and synthetic—whichever can be obtained. Consumption was three billion dollars worth in 1946 as against one and a half billion dollars worth in 1941. You will be able to buy larger proportions of natural rubber, the supply to catch up with demand some time this year, with lower prices on both natural and synthetic to materialize. Rubber prices are destined to be more stable than in pre-war years, partly because of the steadying influence of the synthetic. Natural rubber comes out of the Far East in increasing quantities, world output soon to reach 1,200,000 tons yearly. There is at least equal capacity for production of synthetic.

Cadmium Aids Copper's Tensile

The copper cable makers have lost some of their markets to the aluminum cable manufacturers, partly because the lighter weight of the aluminum, with steel core, means use of fewer poles. Tensile strength of copper cable is now being enhanced with the addition of a small amount of cadmium, again providing for longer tensile strength of copper suggests spans. This method of increasing other applications.

Stainless Steel Sheets

Thank goodness there is one type of steel sheet that has just become plentiful—stainless steel. Many manufacturers have been attracted to the possibilities of this glamor steel and have rolled miles of these sheets. Around April 1 it became realized for the first time that there is an abundance for all. Smart fabricators are investigating their possibilities.

Doing Without Industrial Uranium

You will find it no real hardship that the government is now monopolizing the supply of uranium. An important use was in ceramics, porcelain enamels and glass to give certain colors. Peach, jade and gray have largely taken the place of uranium-bearing ivory in modern color schemes for home interiors. Several metals and oxides of some rarer metals, other than uranium, are now being used to obtain special color effects in glass.

Iron Ore Prospects

Don't worry too much about our dwindling iron ore reserves. Newly-developed Brazil deposits promise to prove a Godsend for the United States. Exports in 1947, not necessarily all to the United States, promise to be 400,000 tons, equivalent to 275,000 tons of pig iron, which isn't "hay." Brazil's iron ore deposits are estimated at 22% of the world's total. Ore now mined there runs 68 to 70% iron. Another aspect is the possible adoption in this country of the German Krupp-Renn process to reduce iron-bearing sandstone, shale and other plentiful low-grade ores containing as little as 30% iron.

Much Cheaper Rhenium

Product planners will be wise to scan the price situation of rhenium and ponder how they can use it, say in electric heating devices, incandescent bulbs, radio and power tubes, pen nibs and in antiknock fuels. It bids fair to come down in price with a bang. At the University of Tennessee researchers have found a recovery process that may cut the cost from $800 to $200 per lb. Related to manganese, rhenium is good as a catalyst and for electric filaments. It is highly resistant to hydrochloric acid. The new process recovers rhenium from flue dust obtained in the reduction of molybdenum ore.

AN EDITORIAL

The Case of the Frustrated Gnong

Bacteriologists in the United States are becoming increasingly alarmed over the growing prevalence of the *gnong*, a tiny creature best known for his characteristic habit of trying to move in opposite directions simultaneously. On rare occasions he actually parts company with himself, giving off a faint "pop" (to indicate that he has become a father, for of course the gnong multiplies by division and in this way propagates his species).

In most instances, though, he does not thus dissect himself, but merely develops a gnawing frustration, for which he finds relief by circulating among human beings and infecting them with his own trait. In years past he has inhabited various social groups such as editors, steel salesmen, advertising space buyers and women automobile drivers, who provided him with temporary relief while they permanently acquired his unfortunate condition themselves.

Since about 1933 the gnong has been more or less indigenous to Washington, D. C., among whose highly susceptible population of administrators, politicians and economists he was able to relieve his natural frustration almost at will. Indeed, for several years gnongitis assumed epidemic proportions in the Nation's Capital, as evidenced by underplowing and pig-aborting while millions were hungry, pacifistic neutrality acts that bred wars and a Treasury Department doing inflationary things while an ostensibly deflationary O.P.A. functioned otherwise. At present there seems to be an exodus of the gnong from Washington, although residual infection is plainly evident in the get-tough-with-Russia policy accompanied by military demobilization, and in the Administration's simultaneous demands for lower prices and higher wages.

But the real menace to our nation from the gnong lies in gradually accumulating evidence that a hitherto hardy and gnong-resistant group—the technical men in history—are becoming infected. A broken gnong incisor was found in one who was feverishly designing lightweight machinery but using too-low, 20-yr. old physical property data for his materials, so that his product was all bulked up with unnecessary metal. A gnong patch appeared on another who was specifying the cheapest possible raw materials and then processing them by wastefully costly methods.

A "grade A" truncated gnong indenter was removed from a third who insisted on ±0.001 in. tolerances for a "hold-the-cost-down" job, when ±0.005 in. was plenty. And impacted gnong antennae were extracted from a fourth who specified a low-hardenability steel for a massive part to be through-hardened to a Rockwell C it could never reach at the center.

The gnong has received some fortunate setbacks (for example, it sprained its *nodula posterior* on the engineer who fabricated a high-temperature super-alloy structure by soldering) but by and large the gnong infestation is becoming a serious problem to engineers. A campaign for immunization is developing, based primarily on an infusion of facts directly into the engineer's brain, and remarkable results are reported in every case in which it has been tried. The serum can be bought for a trifling sum from several technical publishers or even obtained free from responsible materials and equipment manufacturers.

We urge all to do everything possible to bring the gnong and his insidious divergent motivation under the earliest possible control.

FRED P. PETERS

EDITORIAL COMMENT

Who Knows Specification "N. A."?

These are tough times for the young engineer—and many an older one for that matter—just to master the many new specifications that have entered the technical lingo during the past generation or two. It would seem that a new "spec" is creeping in with abbreviation of "n.a." that will take its place, in a more limited way, beside psi. and a host of others.

It was only two generations ago that fulfilling a specification was indeed simple. Thus, to see if a pig of iron was according to "spec" it was merely fractured and the appearance of the fracture studied. The only flaws in the accuracy of grading was poor eyesight, poor judgment and lack of experience.

Then came chemical analysis, which was far more accurate than appearance of the fracture. More recently chemical analysis became passe and the manufacturer merely guaranteed performance—let chemical analysis be what it will. Entering the picture, too, were various other considerations such as hardenability, hardenability bands, S-curves, Jominy tests and what have you.

To get back to the "n.a.," which will have considerable bearing in the future. If we are on the threshold of an atomic age there will be new considerations in specifying metals. For one thing, as we learned at the 75th anniversary convention of the mining and metallurgical engineers, to harness atomic power we will need metals of unprecedented purity. Beryllium is one of the key metals, for instance, of the atomic age. We must have absolutely pure beryllium, but so far this has proved virtually impossible, except in the laboratory.

The use of materials in a nuclear chain reactor or "pile" involves consideration of their "nuclear properties," whereas previous considerations involved only external physical and chemical properties.

Hence, a new specification will probably be known by its initials, "n.a.," or "neutron absorption," and the perfect material for many of these exacting qualities will be n.a.-o. [zero]. That's why several metals must be absolutely pure—otherwise they might contain impurities which absorb neutrons. Beryllium, a moderator because of low atomic weight, must be free of such "n.a." impurities.

Dear, dear—the life of an engineer!

—H. A. K.

Oxygen in an Important Role

One does not ordinarily think of oxygen as a material, but its use as such is fast developing into significant proportions.

In processing metals in the form of the oxyacetylene flame, it has long been an important factor. And recently its use in the pig iron blast furnace has demonstrated its value in augmenting the furnace's efficiency.

Now comes the startling news of its application to the open-hearth steel furnace. A large American steel company has demonstrated that, by its judicious and efficient application to the bath of two of its 200-ton furnaces, the time in producing a heat of steel has been and can be reduced about 50%. This would indicate that the company will be able to double the output of its 14 furnaces if the oxygen technique is applied to all of them.

This means that it is possible to double the steel-making capacity of a battery of open-hearth furnaces without building any more furnaces—a truly significant development of which more will soon be heard. It means more steel from the present furnace equipment of the country, and more sorely needed steel for the manufacturers of industrial products in general.

—E. F. C.

Gaging in the Production Line

When planning production pr cesses, dimensional inspection of met products right in the production line not always given the attention it d serves. In the old time metal workin shops, when parts were practically han made, often by one person, gaging w performed at the machine and by th same man who produced the par With the introduction of mass produ tion techniques, gaging and dimen sional inspection was frequently move away from the individual machine an to the end of the line for inspectin only finished products. Now the tren again seems to be towards movin gaging back to the machines.

Gaging directly at the machines in stead of in separate departments ha several advantages. One of these is tha it avoids excessive waste of materia and time. Where a product is made u of several individual parts and gage after assembly, the entire finishe assembly may have to be scrapped i one part does not meet requirement Gaging at the machines where th individual parts are made is one wa of avoiding this waste. Where mor than one operation is involved in mak ing a part, gaging immediately afte each operation can often eliminat further work on rejects. Besides this the trouble that is causing the reject can be traced directly to its source.

Another very important advantage often overlooked, is improvement o the workers' morale and efficiency. Mos workers get a certain amount of satisfaction out of knowing personally tha they are doing a good job. By bein able to inspect their own work, the know exactly what quality job they ar doing. In addition, gaging right at th machine eliminates the bad psychological effect produced when the inspection department either returns unsatisfactory parts to workers or notifies them that their work was rejected.

Because of these advantages many automatic gaging instruments have already been developed for dimensional inspection directly at machines. And as the needs increase, more of these devices to fit specific requirements will be made available.

—H. R. C

Materials & Methods | THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

MAY 1947

All types of transportation equipment are being studied to determine where weight economies can be made. This locomotive cab is being fabricated of aluminum. (Courtesy: Aluminum Co. of America.)

Weight Economy in Engineering Design

by **WALTER A. SEMMION,** *Aircraft Research & Development Div., Willy-Overland Motors, Inc.*

THE EFFICIENCY OF ANY TYPE of transportation equipment, from an operational standpoint, depends largely upon its actual weight when empty and its ability to carry the maximum useful load within the limits of its gross weight and specified performance. In such products, weight economy is absolutely essential. In the design of other products, such as electrical appliances, weight economy often results in a more salable product or in substantial savings in manufacturing costs.

Choices of materials and designs based on the principles of weight economy can result in a much more efficient product and help reduce manufacturing costs.

Careful weight control, if undertaken in the preliminary stages of design of any vehicle, usually results in an efficient product incorporating maximum usefulness at the least manufacturing and operating cost. A pound saved in any part of a primary structure, accessories, power plant or fixed equipment will result in weight saving in adjacent parts, or fittings, which, in turn, permits lower gross weight, less fuel consumption, improved operational performance or greater payload.

In the design of consumer goods, weight control, which insures the use of the lightest possible materials, increases the speed with which the various assembly

Table I—Properties of Engineering Materials

Strength-Weight Ratios of Engineering Materials						Relative Weight for Same Strength			
Material	Unit Weight Lb./In.^{3}	Ultimate Tension, Psi.	Ultimate Compression, Psi.	Ultimate Shear, Psi.	Ultimate Bearing, Psi.	Tension	Compression	Shear	Bearing
Steel X4130—Annealed	0.284	90,000	90,000	55,000	140,000	1.00	1.000	1.000	1.00
Stainless Steel—Annealed	0.282	80,000	80,000	70,000	122,500	1.116	1.117	0.780	1.135
Aluminum Alloy 24St—Bar Stock	0.100	62,000	62,000	37,000	90,000	0.511	0.511	0.524	0.548
Magnesium Alloy	0.065	32,000	23,000	18,000	55,000	0.644	0.644	0.699	0.583
Phenol-Formaldehyde Plastics	0.0498	7,000	25,000	6,250	32,000	2.255	0.631	1.543	0.767
Fabric Reinforced—Laminated	0.0498	18,000	20,000	5,000	25,600	0.877	0.789	1.929	0.959
Urea-Formaldehyde Plastics—Paper Base	0.0541	8,000	25,000	6,250	32,000	2.143	0.686	1.676	0.833
Thio-Urea Plastics—Paper Base	0.0541	9,000	30,000	7,500	38,400	1.905	0.571	1.397	0.694
Methyl-Methacrylate Resin—Molded	0.0430	5,000	12,500	3,125	16,000	2.725	1.090	2.665	1.325
Cellulose Acetate—Molded	0.0476	5,250	19,000	4,750	24,300	2.873	0.795	1.941	0.965
Improved Wood (Plastics)	0.0243	10,000	6,250	1,850	6,250	0.770	1.232	2.544	1.917
Duramold Type I									
Maple	0.0281	—	7,500	1,520	2,170	—	1.187	3.580	6.383
Birch	0.0255	—	7,300	1,300	1,590	—	1.107	3.799	7.906
Douglas Fir	0.0190	—	7,000	810	1,300	—	0.860	4.543	7.205
Poplar	0.0162	—	5,000	800	810	—	1.027	3.922	9.859
Spruce	0.0160	—	5,000	750	840	—	1.014	4.131	9.390
Basswood	0.0150	—	4,500	720	620	—	1.056	4.035	11.926

operations can be carried out. Further economies are gained through the lower cost of shipping lighter weight products.

Efficient weight control depends on the proper selection of materials and on the manner in which they are joined together to form the completed product. Much depends on the skill of the designer. In the design of an airplane the prime object is to obtain maximum strength at minimum weight. In the design of most other products, the possible saving obtainable from weight control must be balanced against the possible added expense of lighter weight materials and the adaptability of the various possible materials to mass production fabricating and assembly methods.

Materials Selection

The ideal structural material should possess at least several of the following properties: high strength to weight ratio, good bearing and shearing qualities, high modulus of elasticity along any direction, ability to absorb and dissipate vibration energy, low unit weight, immunity to corrosion and inability to absorb moisture, uniform properties under variable climatic conditions, ease of fabrication and low cost. Selection of a material for a particular part usually requires a sacrifice of one or more of these properties to obtain the best combination available for the part.

The strength properties of many of the common engineering materials and a comparison of the relative weights to give the same strength as annealed SAE X4130 steel are given in Table 1. These values are a general indication of some possibilities for weight economy.

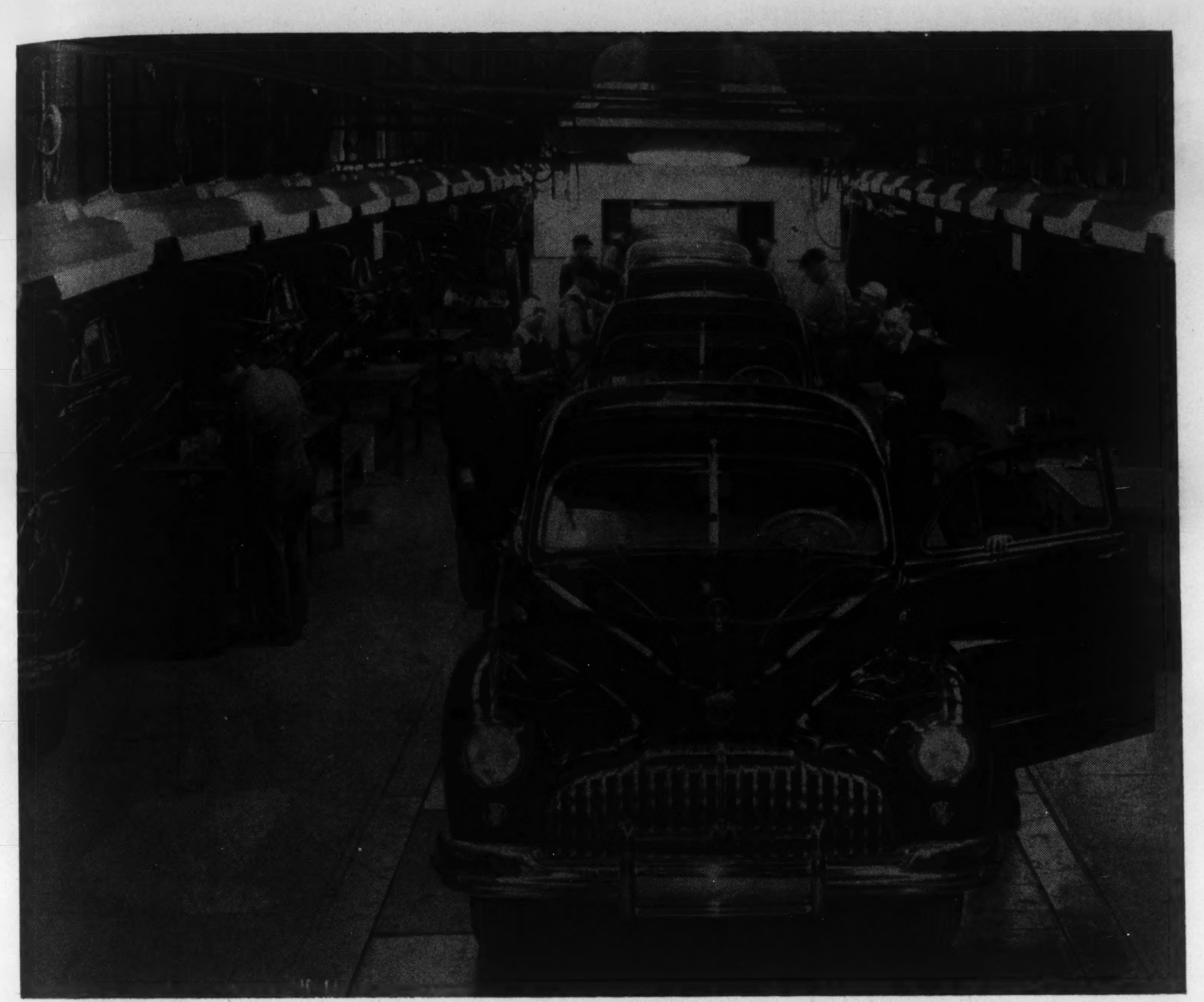
The necessity for stiffness and, therefore, the modulus of elasticity governs the structural design of many parts. Although the high density materials, such as the various metals, possess great ultimate strength, strength is not the primary requisite for the design of moderately loaded structures, such as panels. Low density materials which are capable of taking moderate loads without premature buckling are selected for many such parts.

The ability to absorb vibration energy is often a desirable quality. It is present in various degrees in different structural materials.

Material	*% Energy Absorption*
Low pressure phenolic plastics, paper or fabric base	22 to 25
High pressure phenolic plastics, paper base	16 to 18
Plywood, mahogany and walnut	11.0 to 12.0
Zinc	12.0
Aluminum alloy	1.0
Low carbon steel	0.2

Aluminum alloy structures can, in many instances, be designed to replace steel with definite saving in weight. Stress, severe forming, welding and corrosion are limiting factors in selecting magnesium alloys. Magnesium alloys should be considered for lightly stressed and nonstructural parts that are not exposed to the danger of corrosion. Magnesium can be used for light supports, diaphragms, partitions, removable inspection panels, housings, or brackets.

In general, when steel is used, high physical properties obtained by quenching and drawing should be



Labor efficiency in assembly is increased where the lightest suitable materials are employed, because of less worker fatigue. (Courtesy: Buick Motor Div., G. M. C.)

specified to insure maximum weight economy. Requirements for resistance to impact or limitations in machinability should be prime considerations in determining the maximum strength levels to be specified. Care should be taken that the specified alloy content of the steels is sufficient to insure hardening throughout the heaviest sections of the parts. Improvements in heat treating techniques and the development of carbide cutting tools has greatly increased the hardness levels at which steel can be economically machined.

For parts in which stresses are fairly low, the use of plastics is ideal for weight economy. The average commercial plastics are 45% lighter than aluminum alloys and 15% lighter than magnesium. Their comparative immunity to corrosion, which eliminates the necessity for surface protection, gives them a further advantage.

Choice of Form

Forgings are generally 75 to 100% lighter than castings serving the same purpose. If the quantity required warrants the cost, forgings should be preferred to either castings or welded parts.

Castings of aluminum alloy are usually heavier than similar parts made of aluminum sheet or even welded steel. Lightly stressed nonstructural castings can be manufactured out of magnesium alloy. Weight saving of 37% is possible, as compared with identical aluminum alloy casting. If stress concentrations are avoided, it is possible to take advantage of the normally high endurance limit of magnesium alloy. Sections and fillets may have to be increased slightly to allow for the lower modulus of elasticity (6,500,000 psi. for magnesium as compared to 10,000,000 psi. for aluminum alloy). This, however, can be done effectively with a weight saving of 25% over the aluminum. Die castings of aluminum and magnesium alloy greatly improve strength and uniformity without adding weight.

Molded plastic parts, when properly designed, offer a combination of low weight, good physical properties and low cost.

For structural members, formed sheet metal sections are much superior to extrusions or rolled shapes. In some instances weight savings of as much as 40%

can be obtained by using formed "J," "U" and "Hot" sections in preference to extruded shapes.

Design Factors in Weight Economy

One of the most important phases of designing for low weight is in the establishment of factors of safety. They should be kept as low as possible and still permit safe operation. In general, they should be the same for all parts of the structure. Progressive safety factors, in which separate factors are used for design load, fitting design, casting allowance, weld allowance and margin of safety, must be eliminated.

The basic structural criteria used in some designs are so inadequate that high ignorance factors must be employed to insure structural soundness. In such cases the inexperienced designer may use high factors to provide a large margin of safety but which, at the same time, increase the weight to the point where efficiency and performance are low.

Simplicity of design requirements should be rigidly adhered to. It is often found that in some designs accessories or fittings can be lightened by proper redesign. Large fillets and gradual approach angles relieve concentrated loads and thus permit the design of efficient joints.

In the design of panels, the use of the lightest possible gage material with an increased number of stiffeners will often lead to appreciable weight economy. Using a lighter gage material is usually more economical than specifying lightening holes. When lightening holes are used, it is better to specify a small number of holes of the maximum possible diameter rather than a large number of smaller holes.

Whenever space limitations permit, the use of beams with large moments of inertia and low cross-sectional area will produce a lighter structure. For column members, large radii of gyration and low cross-sectional area are preferable.

Joining Methods

For the joining of any metallic parts, welding is usually less expensive than bolting or riveting and also permits savings in weight. The weight of the overlaps, rivets or bolts is greater than the weight of weld metal required.

Spot welding or projection welding methods produce joints that are lighter than those produced by arc or acetylene welding methods. Light gage stainless steel, aluminum or magnesium sheet stock can be spot or projection welded at low cost.

When assemblies must be bolted together, the specified bolt length should be just sufficient to permit filling of the nuts. Extra length in the bolts adds nothing to the strength of the assembly but does add weight. Further weight savings can be gained by using clevis head bolts rather than hexagonal head bolts and shear nuts in place of the conventional nut.

In many joining operations, aluminum alloy bolts can be used instead of steel bolts to save weight. For aluminum alloy bolts, large diameters and coarse threads should be used to minimize thread failure during tightening. Aluminum alloy washers permit additional weight economy.

For the joining of plastic parts to one another or to metal parts, many recently developed adhesives are available. These adhesives produce reasonably strong joints that are low in weight and most economical to use.

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Aluminum alloys and low-alloy, high-tensile steels are finding wide use in freight cars, thereby increasing potential pay loads. (Courtesy: Chicago, Burlington & Quincy R. R.)

Unsatisfactory forged aluminum parts can be avoided if stock is checked for hardness and surface defects and if proper dies and heat treatment are employed.

Control of Raw Materials and Processes Assures Quality Aluminum Forgings

by LAWRENCE J. BARKER

THE SMALL ALUMINUM FORGING PLANTS, those just going into business or those already established in the trade, often incur difficulties resulting in the rejection of many forgings that might have been saved if a metallurgist had been consulted or if proper controls had been established throughout the process. Too often an item like consulting can look like an unnecessary expense and the term "proper controls" either sounds expensive or goes by without being fully understood, and thus many a dollar is wasted on fabricating faulty material or using faulty techniques. It is to these shops that this article is directed with the thought that by understanding more fully the process the raw stock receives before being received, by learning the metallurgical basis for certain steps in the forging process, and by realizing the nature and prevention of some of the common defects, the plant owner can put his finger on the sources of likely rejects before they occur.

The rejectable defects are dealt with in two divisions—those directly traceable to the incoming stock, and those due to improper plant practices. Alcoa designated 14S alloy is used as a basis for the discussion since it is the most widely used alloy. The composition of 14S is nominally 4 copper, 0.5 magnesium, 0.5% manganese with controlled impurities of iron and silicon in the amounts 0.5 and 0.9%, respectively—balance aluminum. Other alloys, such as 17S, 25S, etc., or A51S for intricate shapes, having lower mechanical properties, are sometimes used but are similar enough in their characteristics so that the following information is applicable, with modifications, to them as well.

Forging Stock Manufacture

The first step in the manufacture of forging stock, or for that matter any wrought product of aluminum, is to cast the molten alloy in a form suitable for working into the desired shape. In the case of rod up to about 2-in. dia., this form is cylindrical to fit the extrusion press cavity.

The alloy is poured from open hearth furnaces with a usual capacity of 20,000 lb. into tilt-mold ingots of about 2 ft. in length. Since aluminum alloys contract when solidified, these ingots must be headed, or in other words, molten metal must be fed in by hand ladles, or by some other means, to prevent any shrinkage or piping from occurring. Since any defect, such as included foreign matter, head porosity, or piping, will carry through from the ingot to the final product, this step is an important one.

After a softening and homogenizing anneal, these ingots are reheated to the plastic range and extruded by huge presses of up to 7,500-ton capacity into rods of a wide range of nominal sizes. In this process the

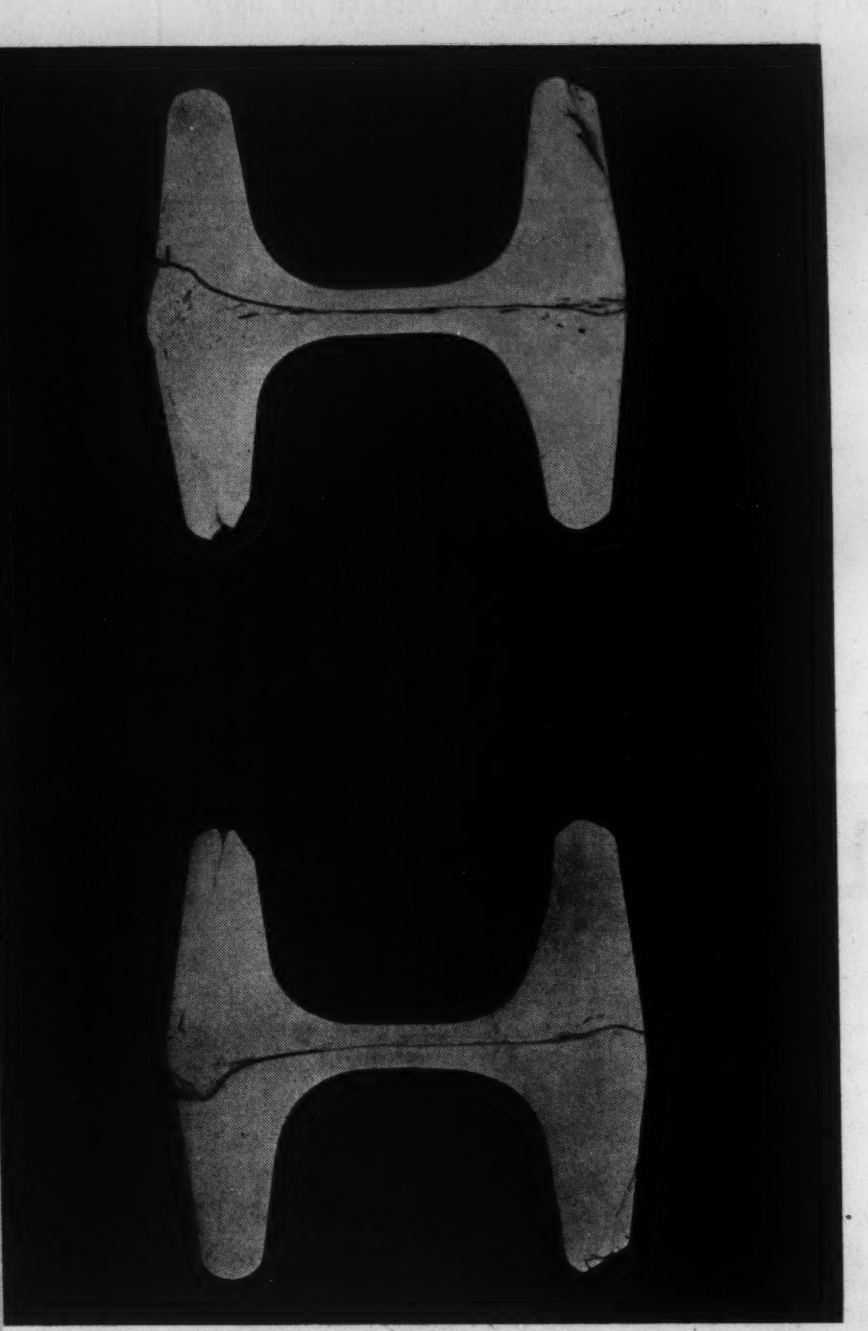


Fig. 1—A photograph of cross-sections of a forging made from laminated extruded stock.

grains, originally having a fairly equiaxed structure, are broken up and elongated in the working direction. The insoluble constituents, impurities, etc., are drawn out in stringer formations sometimes very near the surface of the extrusion. To prevent the outer oxide containing edges of the billet from folding into the rod, a butt of about 10% of the original billet length is left in the press. The very front end of the rod is cut off since it is in the cast form, having received no working in its trip through the extrusion die.

After extrusion the forging stock is sometimes annealed to relieve the hardening imparted during working. This is done in electric or gas-fired furnaces at a temperature of approximately 750 F; a time of over 2 hr. followed by slow cooling is necessary for complete softening.

The material is naturally given a final inspection at this point, cut to size, packed and shipped.

From the preliminary discussion on the basic manufacture it should be apparent where potential dangers lie. First of all, the rod should be in the as-extruded or annealed condition—not heat-treated. This can easily be detected from Rockwell hardness readings. As-extruded or annealed stock will give a reading of under B 10 as against B 66 or over for heat-treated material. The raw stock should be ordered or purchased as forging stock and not merely as rod in order to avoid heat-treated material and to insure maximum forgeability.

Obviously the stock should not show broken surface marks, blisters, or inclusions on the surface since these blemishes will carry through to the final product. Any such pieces should be cut out and discarded at this point rather than carry them through the forging process causing undue expense.

One of the most important items is to be sure that the front end of the rod has been trimmed off, and a simple visual examination will determine this quickly since the as-extruded end has a "lopped-over" appearance and lacks the fresh saw cut. Forging of inferior

Fig. 2—Photomicrograph across the lamination shown in Fig. 1. Wide band is fed-in oxidized material. Smaller oxide stringers are shown running parallel to main vein. (250X)

Fig. 3—Photograph of blisters on a forging. Note how they follow general grain flow.

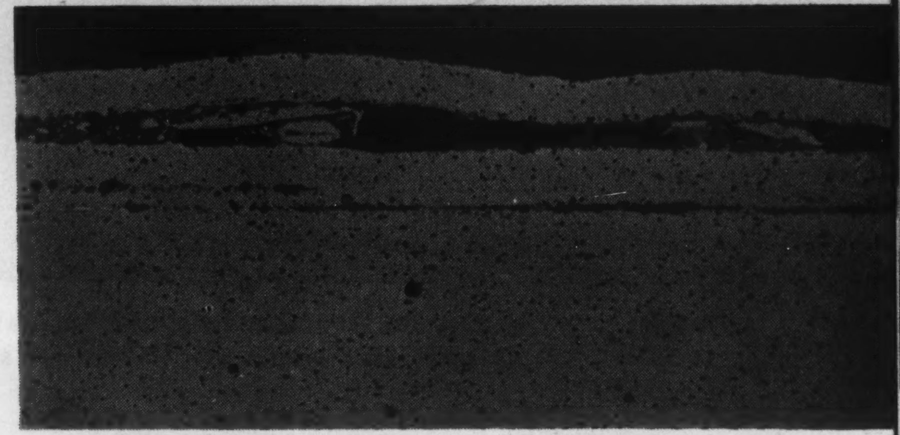


Fig. 4—Photomicrograph in cross section to blisters of Fig. 3. Note stringers of oxide film associated with blister cavity. (250X)

mechanical properties would result from using this unworked material.

The rear-end of the rod can be checked for two additional sources of trouble. The first of these is termed rear-end piping, which is shown in Fig. 1. This forging was made from the rear-end of a rod in which piping was severely indicated. The two sides of the forging could be pulled apart by hand. The corresponding photomicrograph, Fig. 2, shows the wide lamination and parallel bands of oxide.

To check for piping, since it is usually impossible to determine which end of the rod is the rear, the following procedure is suggested:

> From both ends cut a ½-in. slice. Polish one surface of each on fine emery or on a grinding belt. Immerse in a hot solution of 20 to 40% caustic for 5 to 10 min., rinse in water, dip in nitric acid and second water rinse. Any piping will show up immediately since the oxides are more soluble than the aluminum and will thus etch out first.

If these same test specimens are given the regular heat-treatment for forgings, the second source of trouble can be investigated. This investigation is necessary when difficulty has been incurred in getting an intricate shape to form properly from the strong alloys. This is sometimes due to the use of as-extruded stock instead of annealed, or possibly due to using stock that was extruded in a multiple hole die instead of a single.

In reviewing the extrusion process here, a single-hole die will assure maximum working on all sides of the rod. After a critical value is reached certain portions of the rod are in a state, or potential state, of recrystallization. In the one-hole die this portion is formed on the outer shell of the rod, increasing in depth toward the rear of the piece. This shell has received greater working (beyond the critical value) in the extrusion process the actual depth at any section depending on the original grain size, ingot temperature, die temperature, speed of extrusion, etc. This zone or shell is entirely symmetrical with the cross section, in the case of the one-hole die, due to equal working, concentrically. In the multiple die, however, the working is obviously not concentric with the rod and thus forms a crescent-shaped or off-center circle of potential recrystallization. The two zones will have different flow characteristics. This effect is minimized and negligible in the case of the one-hole die rod, due to uniformity of cross section. In the multiple-die rod this uniformity is not achieved, and in severe cases may cause cracking, peeling, etc., in attempts to form intricate parts.

By taking the previously mentioned, heat-treated specimens and swabbing a machined or polished surface with a solution of 25 HNO_3, 15 HC1, and 10% HF. in water followed by a water rinse and quick immersion in HNO_3, the recrystallized zone can be seen.

To alleviate any difficulties arising from this, it is necessary to order the stock extruded in the single-hole manner.

Often, for no apparent reason at all, blisters will appear on the surface of the completed forging. If they follow the general flow lines of the now-distorted rod, they can generally be traced to the result of stringers of oxide film having been extruded near the outer surface of the rod. An example of this type of blistering is shown in Fig. 3; the accompanying microstructure is shown in Fig. 4, in which the small associated stringers can be noted at a depth of 0.005 to 0.025 in. Although it appears that this is merely a surface defect, it cannot be tolerated in the usual forging application. There is no remedy for this defect other than to scrap the piece and, unfortunately

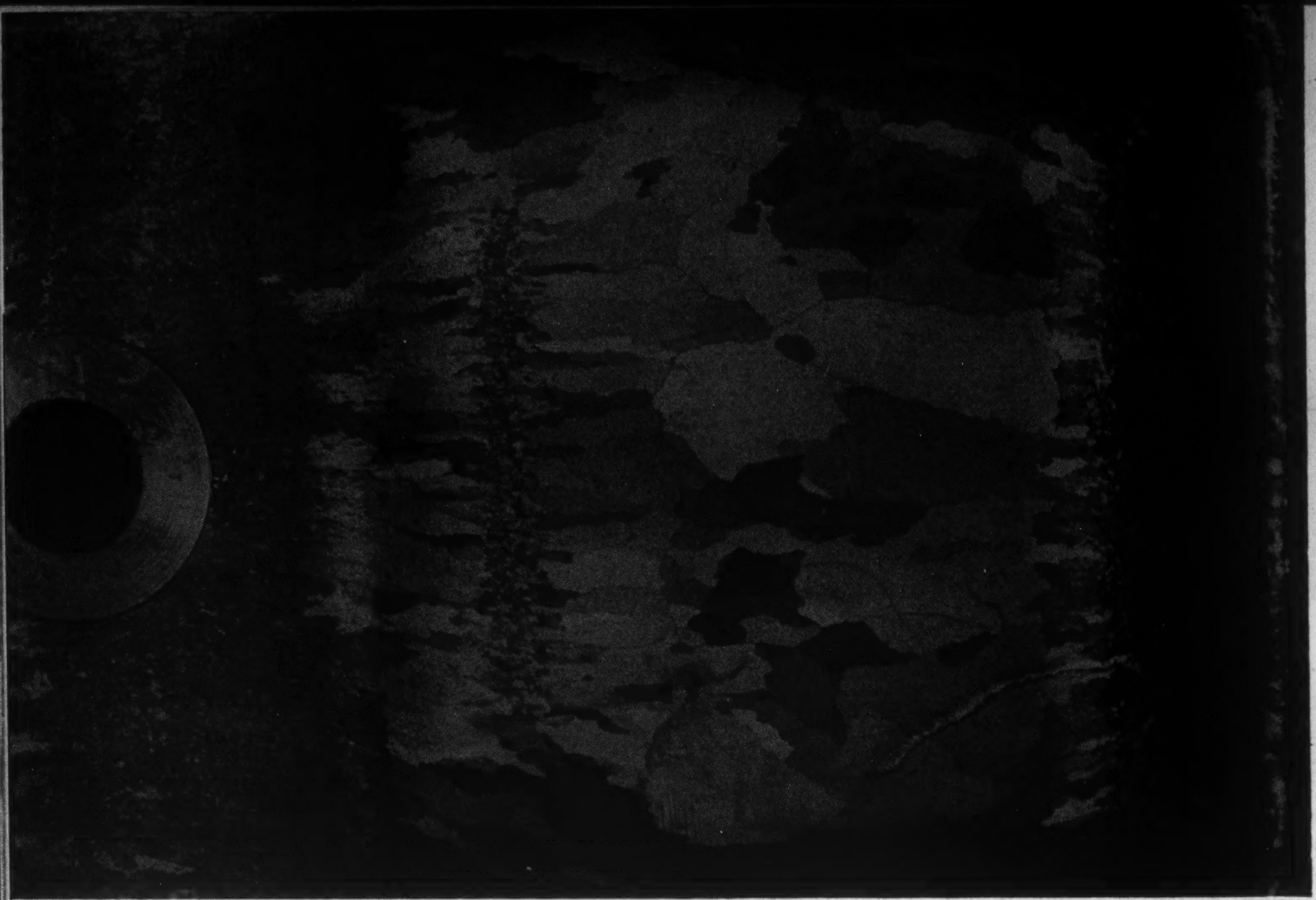


Fig. 5—Portion of a forging showing effect of high temperature oxidation. Note definable grain boundaries. Slight macro etch. (2X)

it is not detected until after heat-treatment. If, by chance, it occurs repeatedly on the same type of forging, the use of larger rod or re-routing the flow of surface metal may overcome it. All blisters are not caused in this manner, however, some of them resulting from porosity in the ingot, die lubricant, overheating, etc., so a fairly critical examination is needed before passing judgment. The other types of blistering are discussed under plant defects; the significant thing to note here is that they follow the flow lines.

If the final properties of the forging are low, and heavy stock, 2½ in. in dia. or greater, has been used, a chemical check by spectrograph can be taken over the cross section to test for segregation. Often, due to the nature of the strong alloys, the center of heavy rod may be below the specified minimum in alloy content and will naturally cause a decided lowering of properties.

The last point to remember in working extruded or rolled rod is that it has inherent directionality imparted to it because of the working process. The grains have a preferred orientation and elongation in the working direction, giving rise to a ductility or workability in this direction of a much greater value than in the transverse direction. This effect is somewhat analagous to the properties of a bunch of straws or a piece of wood with a definite fiber structure, consequently having better properties in the longitudinal direction, and, conversely, can be pulled apart, causing fracture, in the transverse direction with ease. This effect, noted at once in tensile tests, can be taken advantage of in designing the proper flow of the piece and to insure the best properties for the part in service.

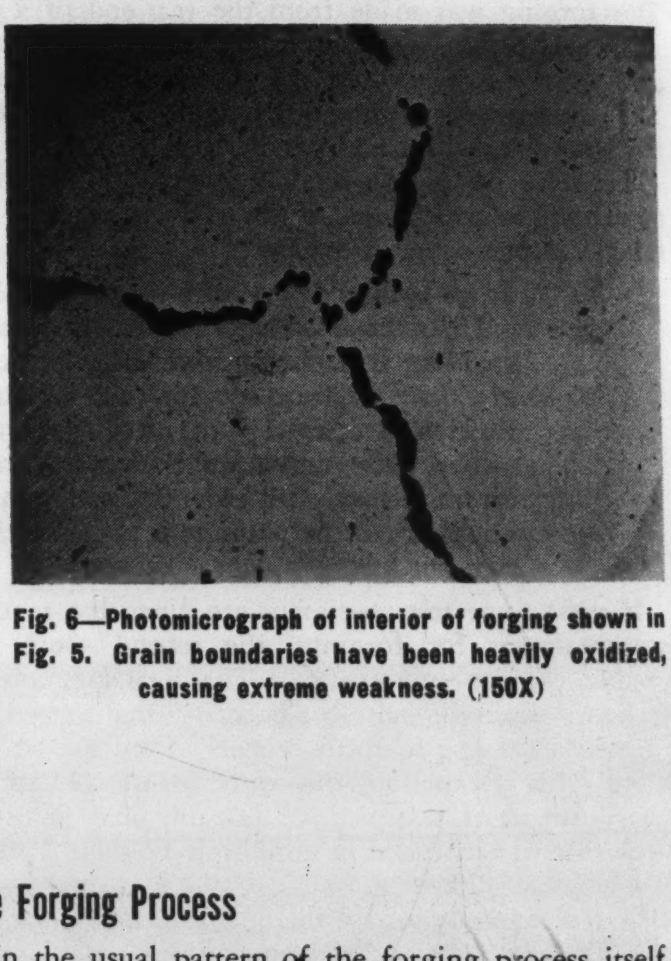


Fig. 6—Photomicrograph of interior of forging shown in Fig. 5. Grain boundaries have been heavily oxidized, causing extreme weakness. (150X)

The Forging Process

In the usual pattern of the forging process itself, the bar stock is first cut into suitable lengths for use, employing saws of various kinds or heavy duty mechanical shears. The pieces are routed through a gas-fired or electric re-heat furnace and emerge at between 700 to 900 F. Enough time is allowed for the material to come up to temperature throughout. Any longer time might result in excess grain growth. This time will vary with the type and temperature of the furnace, thickness of stock, etc.

When the material is at the desired forging temperature, it is shaped in the dies in one or multiple steps by drop, steam or press forges. The pieces are then trimmed and heat-treated by soaking at 950 F for from 4 to 12 hr., from which they are quenched in caustic at 150 F and followed by an aging treatment, at 320 F for 18 hr. or equivalent.

Defects Due to Faulty Techniques

High rejection rates can come from too little control of the important steps in the forging process. A little thing like too high a heat-treating temperature, for instance, if carried on for very many batches of forgings, can run into a considerable loss of time and money, to say nothing of the reputation and good will of the company if the forgings get to the consumer.

Since overheating is one of the major sources of mishap, it will be discussed first. The maximum heat-treating temperature for 14S-T forgings is 940 F. Above this temperature, the eutectic temperature, actual melting of segregated grain boundary constituents occurs, which, upon solidifying, form a brittle, low strength network around the grains and destroy the mechanical properties once enjoyed. There is no recourse but to scrap the material.

Proper control consists of maintaining a uniform temperature throughout the furnace so no hot or cold spots develop, and keeping the temperature within the heat-treating limits. The uniformity can be checked by placing small thermocouples in the corners and at various levels and positions within the furnace. By means of a portable potentiometer the actual temperature at each station can be recorded as the furnace is brought up to heat-treating temperature. Adjustments can be made in the baffles, etc., until the proper uniformity is established. In case of the salt-pot type of furnace, an insulated thermocouple can be moved around the bath to check any gradations.

Keeping the temperature within the limits is necessary to insure meeting the minimum mechanical property requirements as well as to prevent overheating. This requires good pyrometrical equipment and periodic checks and replacements of thermocouples, the exact schedule depending somewhat on the type of equipment, atmospheric conditions, etc.

The time lapse before quenching is important also in assuring good properties and resistance to intergranular corrosion, 10 sec. (from the time the forgings are exposed to air until they are completely immersed) being considered the maximum allowable. More than this time will allow the forgings to lose some of the soluble constituents to the grain boundaries where they will be preferentially attacked under corrosive conditions.

Another defect closely associated with overheating is that of high temperature oxidation. Even with the heat-treating temperature within limits, if excess moisture or sulfur compounds are present in the furnace atmosphere, the grain boundaries are oxidized, forming a brittle network of oxides around the grains and likewise causing low properties and consequent rejection. Such an example is shown in Fig. 5, with the corresponding microstructure in Fig. 6. It is possible in severe cases to see grain boundary separation and sometimes even protrusion with the naked eye. Such cases should be immediately recognizable as burning or high temperature oxidation. This defect can be prevented by using "Alorco compound" in the furnace charge. This forms a gaseous film over the parts preventing attack.

Burning and oxidation can often cause blisters due to the local expansion of the constituents. Scattered blisters result from this and, with a little experience, are distinguishable from the flow line type caused by faulty material. However, blisters can be caused from a third group of factors, such as improper lubricant for the dies, and forged over flashed metal. By close examination of the blister surface, it is possible to recognize the latter types, whereupon the difficulty can be remedied.

Flash line cracks are often numerous and extend to a considerable depth, thereby constituting a serious defect. They occur in large as well as in small forgings, especially after heat-treatment and seem to be more prevalent the thinner the flash in relation to the thickness of section. They occur largely from improperly designed dies with respect to the flash outlets. When flash line cracking occurs, it generally affects a large percentage of the forgings from the responsible die, but can usually be alleviated by allowing more generous fillets or by enlarging flash outlets.

The mechanical properties resulting from correctly forged and heat-treated 14S-T material are given in Table 1. Actual properties will be somewhat higher than these minimum values.

Incorrect heat-treatment can be detected immediately from failure to reach the specified mechanical properties, but often a small plant will not have access to tensile testing equipment. A quick check can be made on the tensile strength by obtaining Rockwell hardness values of the parts. Forging of 14S-T material should give a hardness of Rockwell B-78 or higher, while 17S-T should give a reading of between B-66 and B-72. These values were obtained from tests conducted on numerous lots of forgings and are directly comparable to the minimum tensile strengths listed. Of course, hardness readings do not give any indication of the ductility of the material but act as a reliable guide as to whether the heat-treatment was effective in raising the tensile and yield values. Burning and high temperature oxidation affect the ductility to a greater extent than the tensile values and, therefore, cannot be detected in a hardness test.

Summarizing, if incoming stock is checked for hardness, rear-end piping, and surface defects, and if proper controls such as uniform furnace temperature checks, use of Alorco compound in the furnace charge, and generous allowances made for flash metal, a quality product will be assured with a minimum of rejections.

Table 1—Mechanical Properties of 14S-T Forgings*

Grain Flow	Yield Strength Psi.	Tensile Strength Psi.	Elongation % in 2 In.
Parallel	50,000	65,000	10
Non-Parallel	50,000	65,000	7

**Specification Q Q-A367b*

Since development of a satisfactory nonferrous rod, it is rather easy to salvage defective gray iron castings through readily machinable welds.

Salvaging Iron Castings With Machinable Arc Welds

by DAVID W. DeARMAND AND SAMUEL EPSTEIN*

CAST IRON IS ONE OF THE OLDEST and most widely used metals. Despite the introduction of new alloys and metals, cast iron has maintained a favored place in industry and manufacture because of its low cost and many good properties. Iron is easily cast in intricate shapes, it machines well, and is extremely durable.

It has long been common practice to repair iron castings by welding. In the past, however, electrically welded repairs were generally of poor quality. Too often the welds were weak, porous, and cracked, and, when ferrous electrodes were used, the weld deposits were so hard that machining was impossible. Only since the development of special flux-coated nonferrous electrodes have machinable welds in cast iron been made successfully and easily with the electric arc. Because the machining characteristics of the weld metal are similar to those of cast iron and the fusion zone surrounding the weld is narrow and soft enough to allow accurate machining, advantage can be taken of the speed of arc welding to make machinable repairs with these new electrodes. This has already proved economical in practice.

Castings broken or worn in use have been welded, machined, and reinstalled in much less time than it would have taken to get new parts. Foundries have reduced the percentage of rejected iron castings through the use of these electrodes. In these illustrations of salvaging a defective casting, Ni-Rod, an electrode developed by The International Nickel Co., was used.

Welding with this electrode is no different than welding with conventional electrodes. Ni-Rod can be used with either direct or alternating current. In general, the welding current should be as low as possible for smooth operation, good bead contour, and a good "wash." The choice of electrode size depends on the thickness of the metal to be welded. Heavy deposits are recommended as the fewer the number of passes, the less the stress in the finished weld.

**All photographs for this article were taken by the authors.*

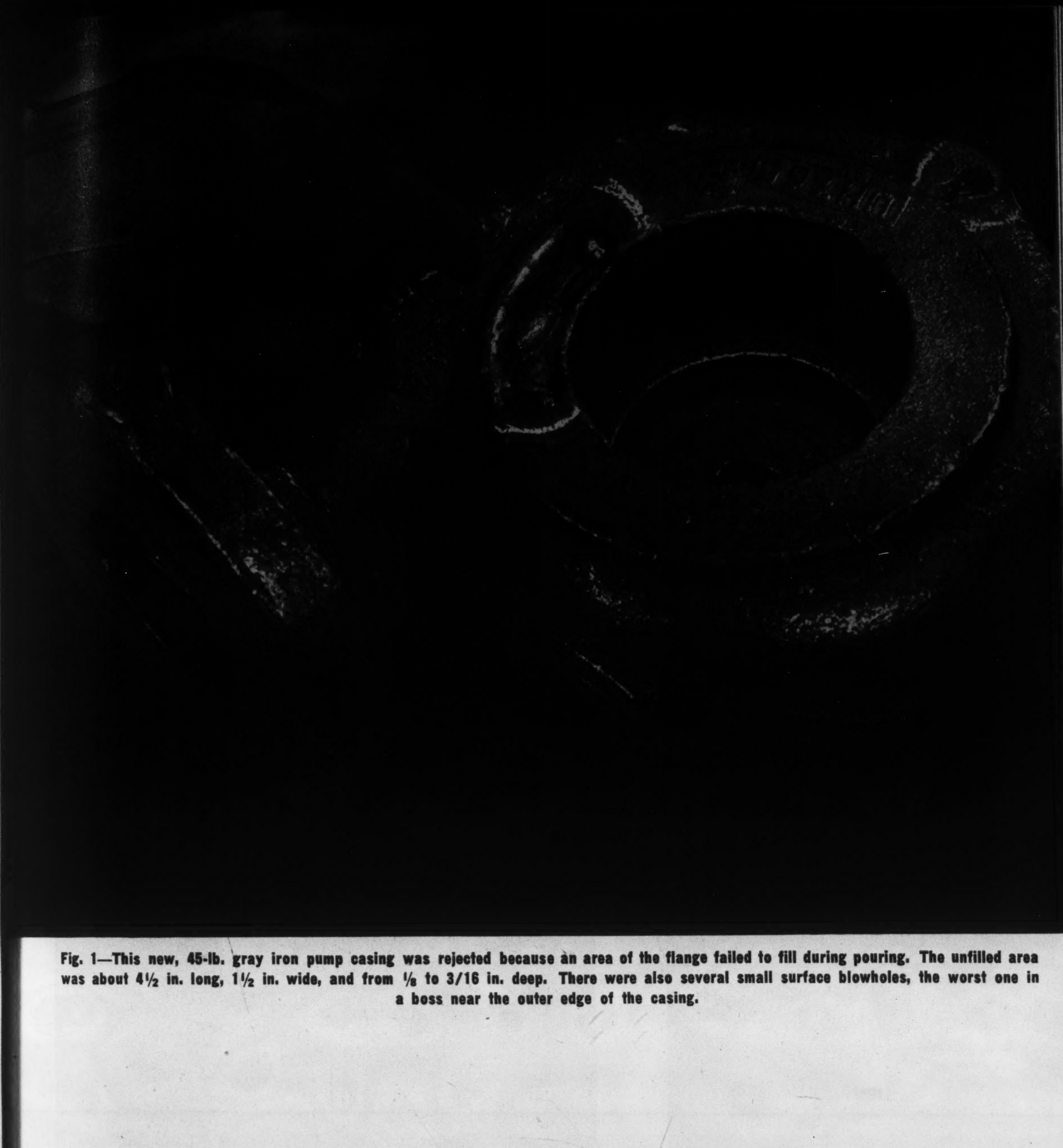


Fig. 1—This new, 45-lb. gray iron pump casing was rejected because an area of the flange failed to fill during pouring. The unfilled area was about 4½ in. long, 1½ in. wide, and from ⅛ to 3/16 in. deep. There were also several small surface blowholes, the worst one in a boss near the outer edge of the casing.

A short arc—about 1/16 in.—is suggested, and the weld metal can be laid down in either straight beads or by weaving. Weaving, however, should not exceed three times the diameter of the rod core being used.

Although preheating is not usually necessary to produce machinable welds with Ni-Rod electrodes, other factors may make this treatment advisable and sometimes essential. Castings that have been in service are frequently impregnated with oil which vaporizes under the heat of the arc and results in a weak and porous bead. Preheating the area to be welded to 750 F will drive off the volatile oil, and make a sound weld possible.

Gassy castings are difficult to detect until welding is begun. However, if the first welding pass is porous and the casting is not oil impregnated, it is safe to assume the casting is gassy. Localized preheat to a dull red will eliminate the gas in the area to be welded. The porous pass should be chipped out, of course, before continuing to weld.

When the shape of a casting is such that internal stresses may result from the localized heat of the arc, preheating is necessary to minimize these stresses. In winter a casting may become abnormally cold, and, therefore, moderate preheat is desirable to prevent stresses resulting from excessive differences in temperature in the iron when welding.

Fig. 2—The defective areas were chipped out with a cold chisel in a pneumatic hammer. Total chipping time was about 10 min.

Fig. 3—Chipping was deep enough to remove all traces of defective metal. The chipped areas were broadened to remove sharp angles.

Fig. 6—Each bead was thoroughly cleaned with a wire brush to remove all foreign matter before another bead was deposited.

Fig. 7—After the major defective area had been filled in, annealing passes were made to further reduce the hard zone. The photograph shows the final annealing pass partially completed.

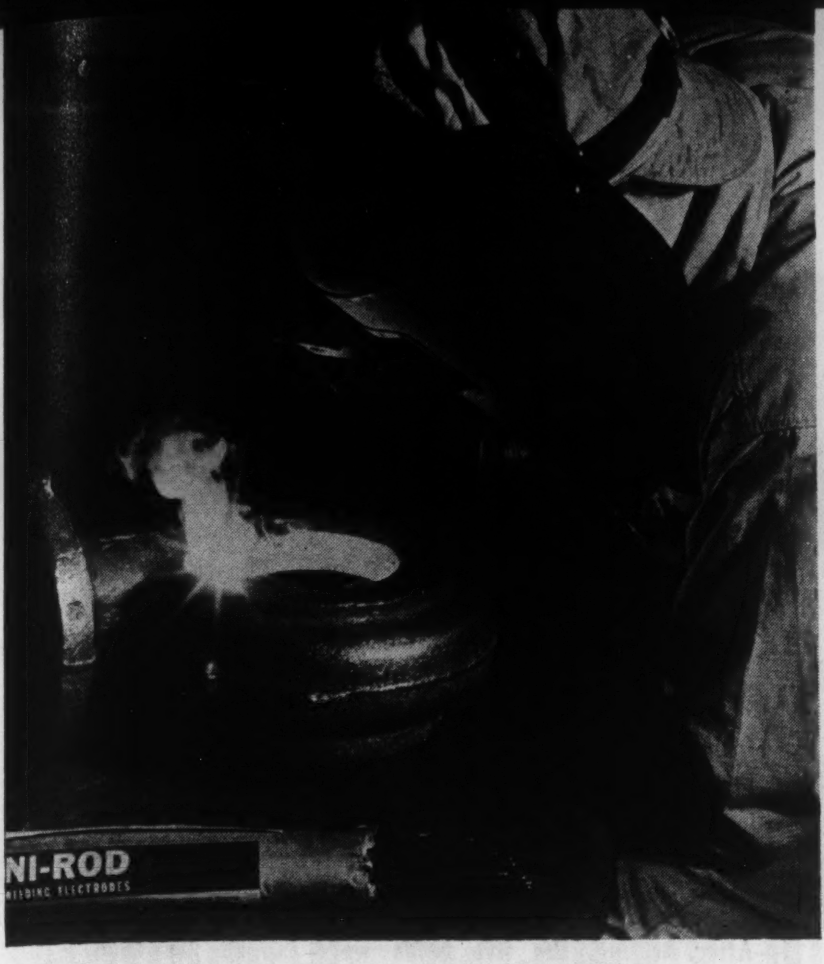


Fig. 4—All welds were made downhand using 5/32-in. dia. Ni-Rod electrodes drawing 110 amp. from a d.c. welding machine. Five weld layers were deposited in the main area to be repaired. There were two beads to each layer, and a slight weaving technique was used to lay the beads.

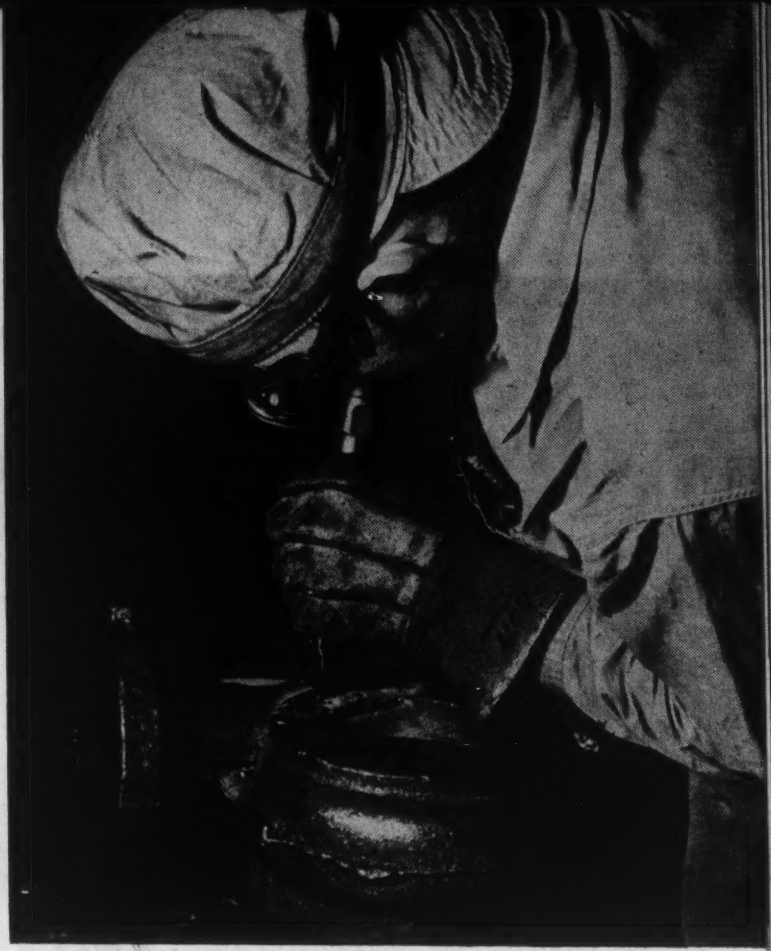


Fig. 5—After depositing, each bead was peened with a pneumatic hammer to relieve any internal stresses that might have been present.

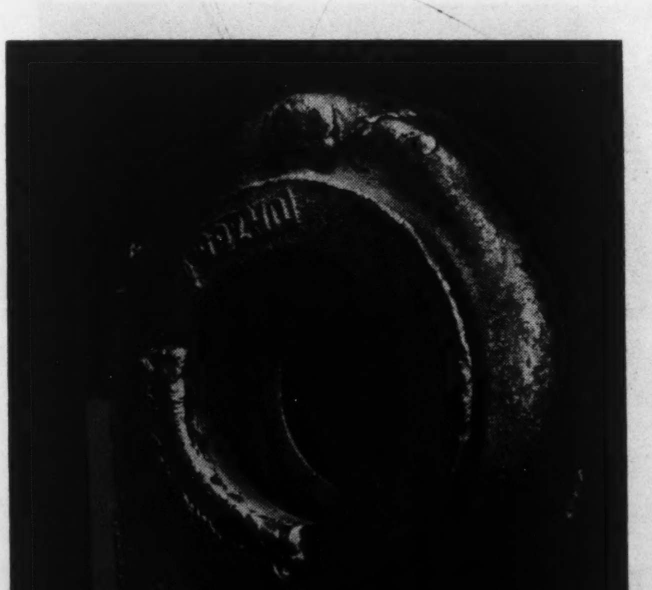


Fig. 8—When completed, the major repair weld was from ⅛ to 3/16 in. above the normal surface of the flange face. Seven electrodes (0.7 lb.) were used for this weld. Less than a single electrode was used on the defective boss and the other surface flaws. Approximately 30 min. was spent welding.

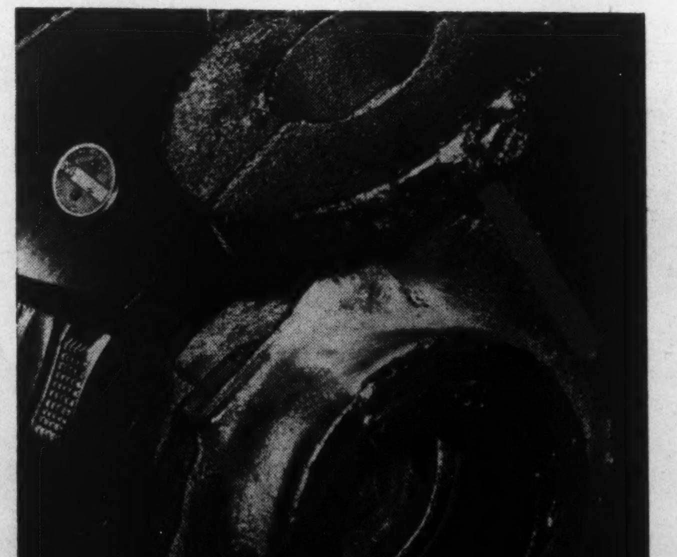


Fig. 9—After welding, the flange face was turned down in a lathe at 185 surface ft. per min. using carbide cutting tool with a 0.017-in. feed rate. The flange bore was machined using the same lathe speed and a feed of 0.012 in. A high-speed tool steel cutter was used for the bore. The lathe was stopped half way through the first cut on the flange face to get this picture.

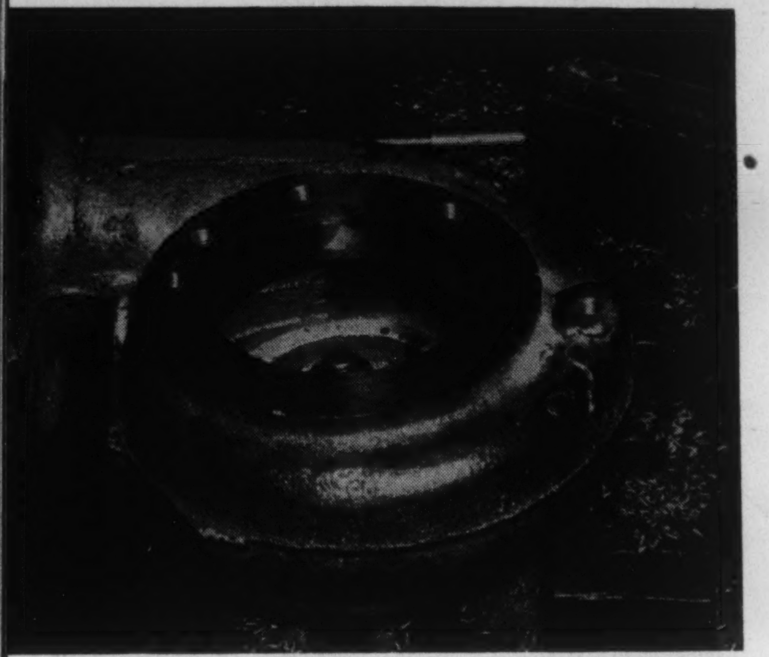


Fig. 10—Under normal manufacturing procedure the machined face of the pump casing would be drilled and tapped at regularly spaced intervals. However, to test the quality of the repair, four 7/16-in. holes were drilled; one squarely in the fusion zone; one in the cast iron about 2 in. from the weld; and two in the weld deposit. A fifth hole was drilled in the boss where the large blow-hole had been filled in.

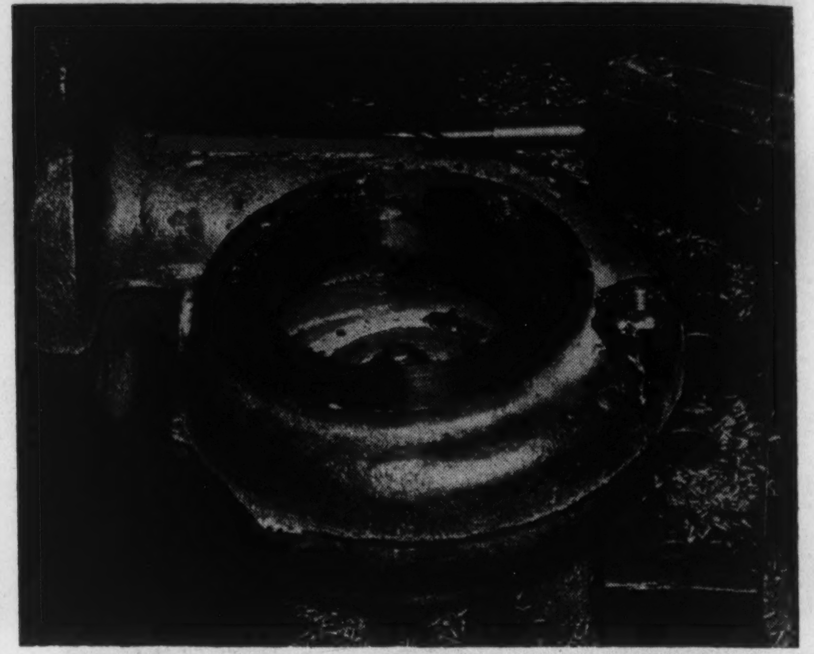


Fig. 11—After drilling, the five holes were tapped. In each machining operation the lathe and drill press speeds and feed rates were those that would have been used had the casting been a perfect one on the production line.

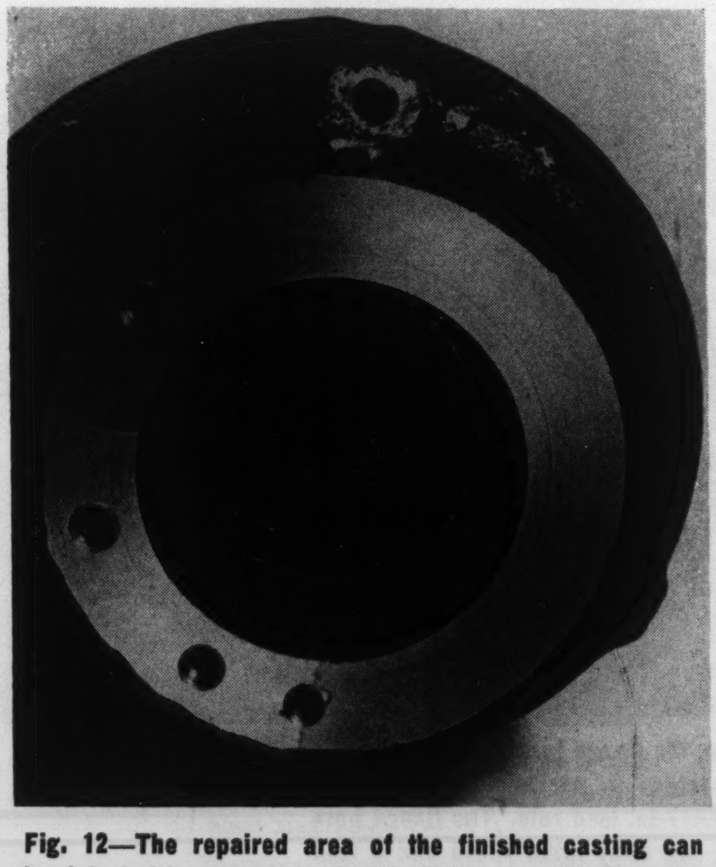


Fig. 12—The repaired area of the finished casting can be detected because it is slightly lighter in color than the gray iron parent metal.

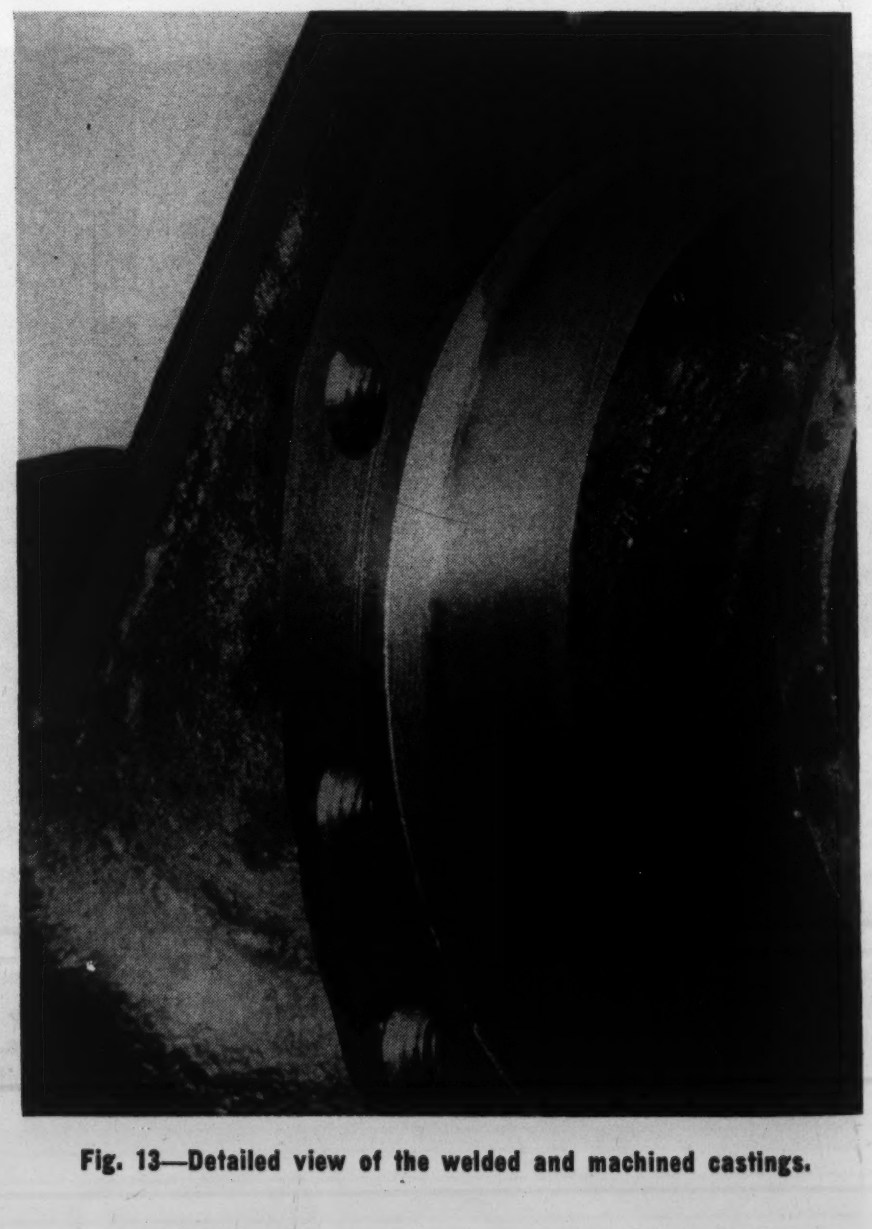


Fig. 13—Detailed view of the welded and machined castings.

With the exception of tolerances possible, machining of laminated phenolics is as simple and as practical as machining of the common engineering metals.

Automatic Machining of Plastics

by **KENNETH ROSE,** *Engineering Editor,* MATERIALS & METHODS

PLASTICS, WITH THEIR VERSATILITY in applications and properties, are always of interest to the materials engineer. The continual development of new types and grades keeps this interest alive in those men that must be alert to the materials situation and its possibilities. Of all the types of plastics now at the disposal of the engineer, one is of especial importance because it is primarily used for structural purposes. This is the group called the laminates.

The laminates are phenolic plastics in which a layered material, usually a fabric or paper, serves as a reinforcement for the resin. The result is a considerable gain in tensile strength, and even more so in impact strength. Combined with the light weight of the resin, this gives the product an excellent strength-weight ratio that will compare favorably with the light metals in many applications.

Use of the layered reinforcing material imposes limits upon the formability of the plastic, however. The laminates can be press formed to simple shapes only, and so are offered in the same standard forms as are metals in stock—sheets, rods, and tubes. A certain amount of postforming is possible, but this does not permit a sufficient range of shapes to be widely applicable. As plastics of this type cannot be melted and cast, nor cold formed, nor forged, as could the metals, machining becomes the most practicable method of fabricating.

The most used machining process in plastics fabrication is sawing. Sheet stock is sawed to working size, tubes or rods are cut to length, blanks can be sawed from any of the various standard forms. Most other standard precedures for machining metal can be used for plastics also, and, in addition, many of the methods of the woodworking shop can be adapted. The usual machine tools are used for producing plastics parts, with little change other than selecting the proper cutting tool, or grinding the tool so that it can most effectively operate with the resinous material.

While large plastics pieces can be economically produced with the standard metalworking machines, much of the total of parts made of the laminated plastics is in small pieces. To obtain the high production necessary to meet competitive prices, such work is routed to automatic screw machines whenever possible. Fabrication with these machines affords the same economies for plastics as it does for metals, and in addition there are several advantages peculiar to the plastics.

Overall characteristics of the laminated phenolics, as related to machining, are:

1. The material is abrasive. Carbide tools will give best results with most jobs, and are necessary for some. High-speed steel tools will give satisfactory performance for many operations, however, and are much lower in cost.

2. Higher speeds are possible, and usually necessary for obtaining highest efficiency. These plastics are machined about as easily as brass, according to shop foremen, and even higher speeds are sometimes desirable.

3. Tolerances cannot be held as closely as with metals. The coefficient of thermal expansion is greater, and more erratic, than with the common metals used in engineering. The resiliency of the material is another factor affecting dimensional accuracy.

4. The resiliency of the resins also requires that tools be ground with greater clearance and rake than for metal cutting.

5. The laminates have definite directional properties. These must be considered in the design as well as in the machining of the material.

Laminated phenolics usually are machined dry and tools given greater clearance and rake than for cutting metals. (All photographs courtesy The Synthane Corp.)

6. A strong phenolic odor is noticed when the laminates are being machined. This is not in any way dangerous.

7. Dry cutting is the rule, in contrast to the machining of steel in a flood of oil.

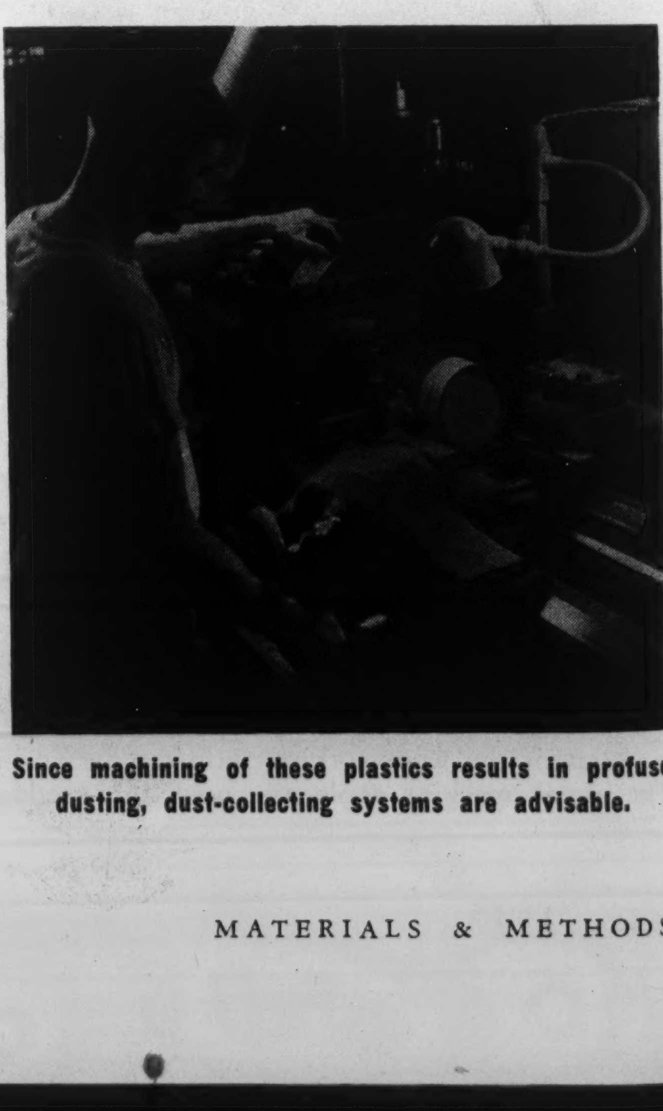
8. Dusting of the material is profuse, and requires the installation of a dust-collecting system.

Screw machine operations follow general practice for machining of plastics, but, as with metals, there must be a sufficient volume of each item produced to permit recovery of setup time and cost of special tools. Tools can be more expensive than for metals, but speeds are higher and cutting fluid costs are saved. Offsetting factors are the cost of installing and operating the dust collecting system, and the loss of value in the scrap.

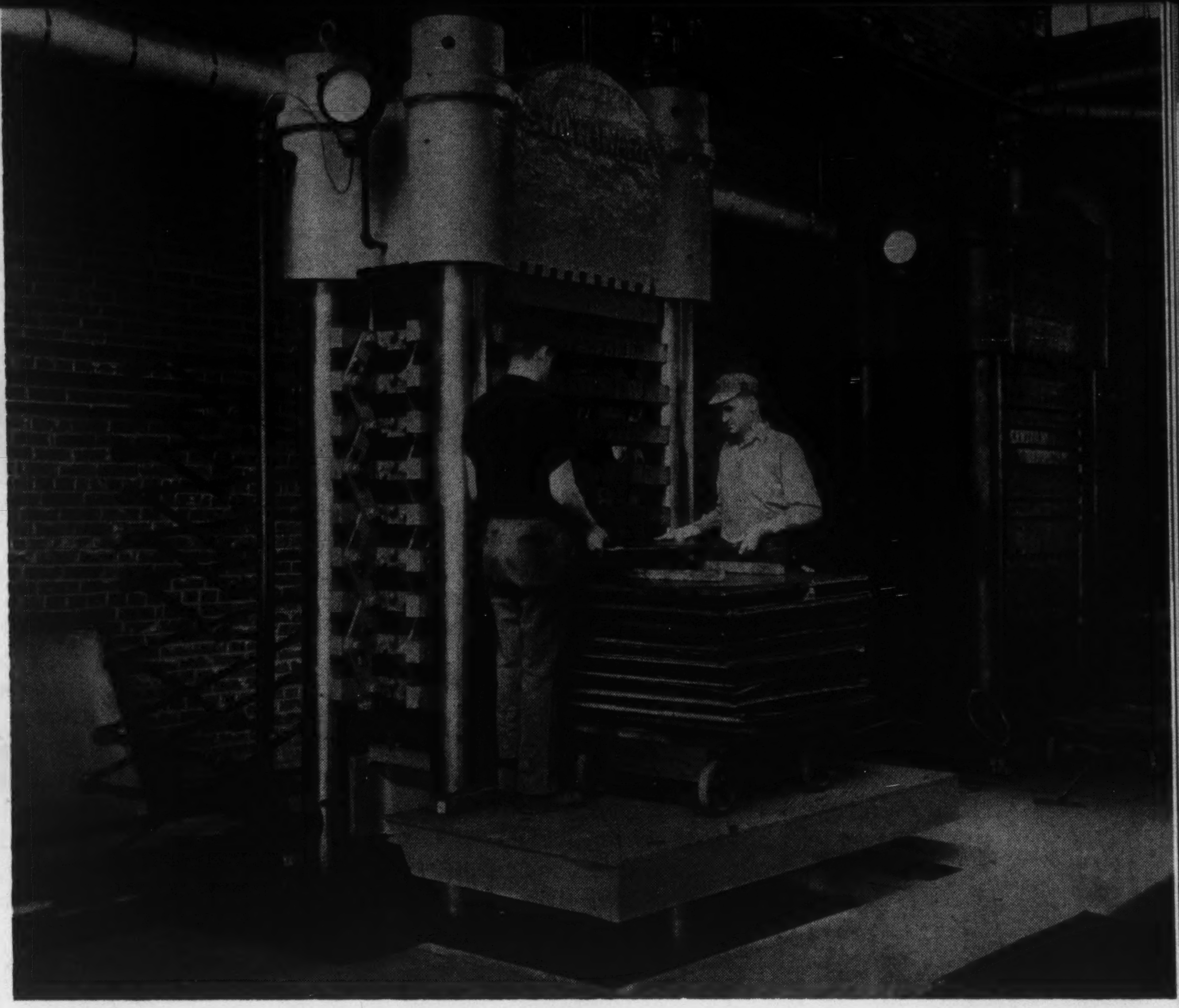
Laminates Used

Materials used are fabric-base or paper-base laminates. A variety of grades are available, in which the type of filler, ratio of weight of filler to resin, and weave of filler (in the case of fabrics) influence the properties of the laminate. Machining grades are usually cotton fabric or cellulose paper laminates. Glass fiber fabric, asbestos fabric, or asbestos paper may constitute the layered material also, but such laminates are too difficult to machine to be readily adaptable to screw machine work. If a special application requires the use of these types, they can be fabricated with the aid of carbide-tipped tools.

For heavy-duty applications, such as gears, a 10-oz. canvas may be used for the laminate. A 14-oz. material is sometimes used when unusually heavy service is required. These heavyweight fabrics cause trouble during machining, as they tend to "fuzz." Also, a heavy, coarse weave of fabric makes difficult the production of fine details in machining, such as small threads or sharp edges. A laminate with a lighter weight canvas, usually 6 to 8 oz., is used for light work. When small parts are to be produced, and fine detail must be preserved in the machine work, a



Since machining of these plastics results in profuse dusting, dust-collecting systems are advisable.



The most readily machinable laminates are those having cotton fabric or cellulose paper fillers. Glass fiber and asbestos fiber and asbestos paper laminates can be machined but not readily on automatic machines.

"linen-base" laminate can be chosen. The fabric is really a finely woven cotton.

The machines used are the smaller sizes of the standard automatic and semiautomatic screw machines. Swiss-type machines are favored for production of some of the smallest pieces, but for the most part standard American equipment is installed. With the fully automatic machines it is not necessary to have an operator for each machine, as his duties consist only of occasional inspection of the work, refilling the magazine when needed, and standing by in case of breakdown or other mishap. If a setup man is available, the number of machines per operator can be increased.

Cams can be made of the laminated plastic, and the cost of tooling reduced in this way. Tool pressures are usually not too high for this material. For the smaller sizes of automatics, ½- to ¾-in. sheet is generally used, while the larger sizes make use of 1-in. stock. Cams may be cut in about half an hour, a prominent fabricator reports.

Magazine feeds are useful for the fully automatic machines in which one operator divides his attention among several machines. The magazine may be loaded with sufficient tube or rod to supply the machine for several hours, and the operator need not be bothered with continual reloading.

Use of a pickup arm and burring attachment on the screw machine will frequently save an additional handling of the piece. This attachment permits the piece to be picked up by the arm after it is cut off from the rod or tube at the end of the regular cycle of operations, swung out of line with the axis of the machine, brought into position against a supplementary tool located near the machine's automatic chuck, and a backfacing, counterboring, or deburring operation performed upon the cutoff end of the workpiece.

Automatic screw machines should have speeds up to about 6,000 rpm., while the semiautomatic or hand-operated screw machines should be capable of speeds of 3,000 rpm. It is the consensus of opinion among users of screw machines for machining plastics laminates that the work should be done at the highest speed possible to obtain a good finish. As the shearing strength of the laminates is low compared with most metals, cutting speeds can be quite high. The abrasive quality of the material militates against use of the speeds theoretically possible, even with carbide cutting tools, but the speeds in use are still quite high judged by those used for steel.

In general, high-speed steel will give satisfactory service for the machining of cotton fabric laminates, while cellulose paper-base types are cut most economically with carbide-tipped cutters. Some companies use high-speed steel tools for paper-base laminates, and report satisfactory results, but the higher speeds and longer runs possible with the carbide tools make their use economical. The use of carbide drills and reamers, carbide taps and chasers, and carbide formed tools is less general than the adoption of carbide-tipped turning or other standard tools, for economical reasons. Most tool rooms hesitate to stock special-purpose carbide cutters unless there is work on hand to justify the considerably higher cost.

Diamond Tools Sometimes Used

Diamond boring is frequently used in machining the plastics laminates. The tools are expensive, but are not strictly special-purpose tools, and their longer life justifies their use in cutting abrasive material. This is especially true in screw machine operations, where setup time is lost time.

While tool life depends to a considerable extent upon the particular job, several fabricators of plastics laminates whose shops include automatic screw machine departments summarize their experience as follows:

1. Diamond tools—do not need sharpening in the course of a run on a machine. They may occasionally break in service; careful handling is necessary.
2. Carbide-tipped tools—may require sharpening about once a day, counting 24-hr. operation as a day.
3. High-speed steel tools—will probably require sharpening every 4 to 8 hr.

Turning tools are ground with about the same rake and clearance as for cutting brass, but practice varies somewhat among the various shops. One large fabricator reports good results by grinding turning tools with 15 deg. clearance, 0 rake. Special drills are available for operations with plastics, and these should be used in screw machine work. They have been modified so as to promote chip removal, by providing steeper twist, wider flutes, and polished surfaces in the flutes. It is good practice to cut the cams controlling the drilling so that the drill is retracted one or more times if the hole is deeper than four times the drill diameter. The drill should be ground with plenty of clearance, to make for free cutting, and the lip should be dubbed as when drilling brass, to prevent grabbing.

Drilling parallel to the laminations has a tendency to split the piece, and should be avoided whenever possible. Because of the resiliency of the laminates, the drill should be slightly oversize, as the material closes in slightly after the drill is withdrawn. Some operators prefer to use a lubricant when drilling deep holes—others state that a lubricant tends to pack the chips, especially the fine dust. The lubricant recommended for use with plastics laminates by the National Electrical Manufacturers Assn. consists of 60% paraffin oil and 40% kerosene. Using 50% of each gives a mixture almost as satisfactory, and slightly cheaper.

When quantities are sufficient, automatic screw machines provide an ideal means of producing small parts of rotational shape.

Threads can be cut with a tap or with a thread chaser. When tapping a hole the use of the paraffin oil-kerosene lubricant is recommended, as it assists in producing a clean thread. Metal cutting taps can be adapted to use with plastics by grinding off two opposite flutes of a four-flute tap, thus providing additional chip clearance. The threads beyond the full depth may be ground off also.

Thread chasers should be ground with a slight negative rake, and with about 30-deg. chamfer on the lead.

When cutting threads with a die in the automatic screw machine, the dies should be given a negative rake of 7 to 10 deg. to prevent "chewing" of the laminate.

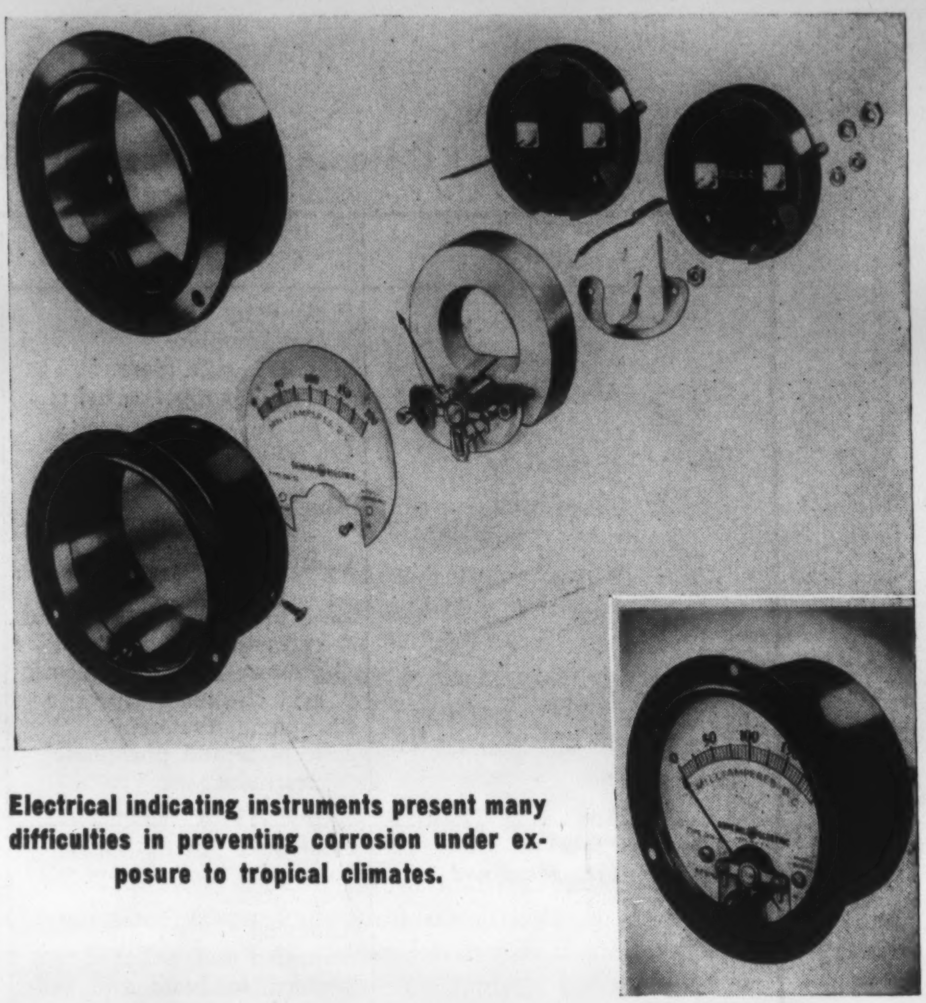
Automatic screw machine operations being performed in fabricating plants illustrate what can be accomplished by this high-speed precision method. At Formica Insulation Co., a metering pump piston tip is being made on this type of machine, with high speeds and light feeds to insure a good finish. Drilling is done at about 10,000 rpm. At Synthane Corp., an automotive distributor bushing is being produced at the rate of 1,000 per hr., using an interesting combination of tools. The piece is first deburred to remove the sharp edge left by the boring and cutoff of the preceding piece, then bored with a diamond tool. A carbide-tipped tool next bevels the outside, and the piece moves out in the automatic chuck. A carbide-tipped cutoff tool next moves into position while a pickup arm swings forward to take the bushing. The piece is cut off, swung out of line by the pickup arm, and the back face is beveled by a high-speed steel drill in the deburring attachment.

A tiny piece intended for a hearing aid illustrates how extremely small parts can be handled on the automatic screw machine. This piece, made from rod, is 0.075 in. outside dia. and 0.048 in. long. It is bored, threaded over the outside with an acorn die, and cut off. The die cuts a thread with 0.010-in. pitch. The machine, turning 6,000 rpm., produces 12 parts per min. at Synthane Corp.

Another unusual piece of work involves the broaching of a paper-base laminated part in the automatic screw machine. The piece, a radio coil form, is first bored, a shoulder is turned on the outside surface, and the spindle is stopped. A broach then cuts five splines on the outside surface. The spindle is started again, and the piece is completed by a cutoff tool.

Three operators keep the 13 automatic screw machines running in that department at Synthane Corp. A shift leader heads the department, and a job setter does the setup work.

Corrosive effects of tropical climates makes necessary the exercise of great care in choice of materials with which to make products for use in such areas.



Electrical indicating instruments present many difficulties in preventing corrosion under exposure to tropical climates.

Materials and Finishes for Tropical Service

by C. D. COOK and C. MERRITT, Jr., *Works Laboratory, General Electric Co.*

WITH THE ADVENT OF WORLD WAR II, equipment manufacturers, especially those in the communications field, were faced with the all-important problem of protecting their equipment properly for sustained service under world-wide climatic conditions. Prior to the war, most electric instruments were supplied with component parts protected to meet only indoor conditions normally experienced in the United States. Finishes were simple. In general, all nonferrous metals were finished to improve only their appearance, a light nickel plate being one of the more popular finishes. Rarely were finishes employed for protection against corrosion. Ferrous alloys were usually oxidized, electroplated, or painted to provide mild corrosion resistance.

Although mild salt spray tests were sometimes required, the choice of finishes was left primarily to the manufacturers. However, reports of corrosion in the field indicated the urgent need for tests duplicating actual service conditions. It became apparent that salt spray tests alone would not suffice.

Humidity Testing Procedure

One of the first attempts to duplicate actual tropical conditions was to subject the parts to a constant high humidity test consisting of exposure for a period of 24 hr. at 82 C (179.6 F) and a relative humidity of 95 to 100%. This test was often supplemented by a 50-hr. salt spray test.

In some instances, electrical instruments were required to operate satisfactorily in accordance with given specifications after being subjected to humidity tests. In other instances, evaluation was made on the basis of the visual evidences of corrosion. The examiner decided what type of corrosion might prove harmful to proper operation. This left wide latitude for judgment. Differences of interpretation caused much confusion. The introduction of this test was a big step forward. It showed that many materials, including commonly-used unprotected cadmium and zinc plates, were unsatisfactory for tropical service.

This test had one important shortcoming. Little condensation resulted from operation at constant temperature and constant humidity. Experience had shown that condensation, which produced electrolysis between unlike metals and dimensional instability of organic compounds, particularly plastics, caused the major difficulties encountered. A closer approach to actual operating conditions was reached when instruments were subjected to cycles of variable temperature and humidity designed to produce condensation.

Table I—Corrosion Resistance of Various Materials and Finishes

Material	Finish	*Hours Salt Spray	Results of Salt Spray Test
Cold Rolled Steel	Zinc plate	4	Gelatinous white corrosion products developed
	Cadmium plate	5	Gelatinous white corrosion products developed
	Copper-nickel plate	20	Rusting at pores and in recesses of assembly
	Cadmium-copper-nickel plate	50	Rusting and cadmium corrosion at recesses of assembly
	Cadmium-tin plate	100	Rusting and cadmium corrosion at pores and in recesses of assembly
	Zinc plate and Cronak	200	Gelatinous white zinc corrosion products developed
	Cadmium plate and Cronak	400 +	Gelatinous white cadmium corrosion products developed
	Zinc plate and formic acid chromate dip	400 +	Gelatinous white zinc corrosion products developed
	Cadmium plate and formic acid chromate dip	400 +	Gelatinous white cadmium corrosion products developed
	Phosphate treatment	10	Sporadic rusting over entire surface
	Zinc plate and phosphate treatment	15	Sporadic white corrosion products of zinc
	Oxidize—gun metal	4	Rusting
Stainless Steel— Type 416, Machined	Passivated	—	Rusting over 50% of area at 50 hr.
	Polished	—	Pits over 30% of area at 50 hr.
	Annealed	—	—
	Annealed and polished	—	—
	Welded to brass and polished	—	Rusting over 30% of area at 50 hr.
	Chromium plated	50	OK, no corrosion
Type 430, Machined	Passivated	—	—
	Polished	—	Pitted over 50% area at 50 hr.
	Annealed	—	—
	Annealed and polished	—	—
	Welded to brass	—	—
	Welded and sanded	—	—
Type 430, punched and drawn	No finish	—	—
Type 347	No finish	200	OK—no rusting
	Annealed	—	
Wrought Aluminum	No finish	50	Gelatinous white corrosion products
	Anodized	250	OK, no corrosion
	Alrok	200	OK, no corrosion
Aluminum Castings	No finish	10	Heavy gelatinous white corrosion products
	Anodized	250 +	Very slight corrosion at pores after 50 hr.
	Chromate	200 +	Sporadic spots of corrosion after 30 hr.
Yellow Brass-Copper	No finish	10	Green corrosion products
	Nickel plate 0.0005 in. min.	200	OK, no corrosion
	Chemical blackenings or "oxidize"	10	Green corrosion products
	Tin plate 0.0005 in. min.	200	OK, no corrosion
Silicon Bronze and Beryllium-Copper	No finish		Green corrosion products soon develop
Zinc Die Cast	Chromate	200	Sporadic corrosion
ASTM B86-43 Alloy No. 23	Formic acid chromate dip	200 +	No corrosion
	Phosphate	30	Gelatinous white corrosion products
Magnesium Die Cast	Chromate	200	Slight corrosion at porosity in coating

* Salt spray test—ASTM Bulletin B-117-44T, Rev. June 1944

Several temperature and humidity cycles have been developed by various testing agencies to reveal specific weaknesses in materials and protective finishes. The most widely used procedure is a test cycle of 6 hr. at 65 C (149 F) and 95% relative humidity followed by an 18-hr. period in which heat is reduced to room temperature and the relative humidity is allowed to increase to 100%. Tests on completed instrument components and accessories were made for 1, 2, 5, 10 and 15 cycles. The results of these tests showed severe corrosion of many common metals, and dimensional changes and deterioration of many organic materials.

†Cycles	Results of Humidity Test
1	Voluminous loose white zinc corrosion products
1	Voluminous loose white zinc corrosion products
1 to 2	Rusting at pores and at recesses of assembly
2	Rusting and cadmium corrosion in recesses of assembly
5 to 15	Rusting at pores and recesses—some evidence of cadmium corrosion at points on surface
1	Voluminous, loose, white zinc corrosion products developed
5 to 15	Voluminous, loose, white cadmium corrosion products developed
less than 1 cycle	Voluminous, loose, white zinc corrosion products developed
less than 1 cycle	Voluminous, loose, white cadmium corrosion products developed
1	Sporadic rusting over entire surface
1	Sporadic powdery white corrosion products of zinc
1	Rusting
1	Rusting
1	Improved over passivated but rusted in localized areas
5	Sporadic rusting 20% area rusted by 15th cycle
15	Slight rusting
1	Rusting at welds
15	OK, no corrosion
5	Sporadic rusting
1	A few rust spots developed on 1st cycle but did not increase up to 15 cycles
10	Slight rusting
15	Very slight rust spots
1	Rusted at welds
1	Rusted at welds and at other spots
15	OK, no rusting
15	OK, no rusting
1	Developed thin film of rust, but did not increase
15	Rare traces of fine white powder
15	OK, no corrosion
—	—
—	—
15	OK, but very slight trace of white corrosion at pores in anodic film
—	—
2	Heavy tarnish and some green corrosion
15	OK, no corrosion
2	Green corrosion products
15	OK, no corrosion
15	No corrosion, but slight tarnish
1	Powdery white corrosion products
1	Voluminous powdery white corrosion products
1	Sporadic white powdery corrosion products
5	Slight sporadic corrosion with little growth up to 15 cycles

† Humidity test—One Cycle: 6 hr. at 65 C and 95% r.h. followed by 18 hr. of condensation

Humidity Test Results

Results of humidity and salt spray tests on several metals with various types of surface finishes are given in Table I. These results were obtained in the course of developing satisfactory finishes for a variety of specific parts or sub-assemblies for electrical instruments to be used under tropical conditions. Results, such as those obtained on cold-rolled steel that had been zinc plated and chromate dipped, show the inadequacy of using only the salt-spray test as a criterion of corrosion resistance.

Thousands of tests were carried out in determining the best finishes for specific parts since each part or sub-assembly presented some special difficulties. In developing a finish for an instrument frame and core assembly, consisting of a brass frame and a carbon steel core, more than 10 different finishes and base metals were tested. Ordinary copper and nickel plate combinations were unsatisfactory because of porosity and the inability to "throw" the plate into the corners of the assembly. Various types of zinc, cadmium and tin plates were found to produce objectionable corrosion products in humidity testing. To obtain a satisfactory assembly it was necessary to use a stainless steel core and to apply a heavy chromium plate for added protection.

The most difficult problem involved in any design to meet severe corrosion conditions is that of assemblies in which dissimilar metals come in contact. Table II summarizes the electrolytic behavior of certain materials.

Table II—Electrolytic Effects Under Salt Spray and Humidity

Material Being Corroded	Material Causing Corrosion
Ferrous Alloys, Stainless Steels, Brass and Other Copper Alloys	Because of the relatively low position of these materials in the electromotive series, little electrolytic corrosion occurred. An exception was thin nickel plate which accelerated the corrosion of ferrous alloys (other than stainless steel) and copper alloys. This condition was particularly pronounced in salt spray.
Aluminum Alloys	Nickel, copper alloys, and ferrous alloys caused severe electrolytic corrosion in salt spray and humidity. Exceptions were high chromium and 18:8 stainless steels, and nickel which caused little difficulty in humidity testing.
Zinc and Zinc Plate	Nickel, copper alloys, nickel silver, and all ferrous alloys caused severe electrolysis in both salt spray and humidity. Aluminum and cadmium plate caused little corrosion.
Magnesium	All metals caused some corrosion with magnesium in salt spray. Aluminum, zinc and cadmium gave the best results, but even with these, some form of organic insulation was desirable. The same general effects were observed under high humidity conditions, but the degree of corrosion was far less than was anticipated.
Cadmium Plate	Nickel, copper alloys, and ferrous alloys caused severe electrolysis in both salt spray and humidity. Immersion chromate finishes had no effect in arresting this corrosion. Aluminum provides a corrosion-free contact.

Choice of Metals and Finishes

Several general conclusions can be drawn from the work which are far more useful than the specific results of any test.

No finish schedule is completely satisfactory for ferrous alloys other than stainless steels. The most satisfactory schedule is zinc plate, phosphate, baked alkyd-iron oxide primer, and baked topcoat. With stainless steels, a single coat of baking enamel suffices whenever a finish is needed.

Low chromium content (13%) stainless steels corrode under nearly all conditions. Higher chromium stainless steels (18% or higher) are generally satisfactory except where stainless properties are destroyed by fabricating operations such as welding and annealing; 18:8 stainless steels are satisfactory except when annealed.

Wrought aluminum alloys are satisfactory when anodized. Castings, when anodized, show a tendency toward pinhole corrosion where breaks occur in the film. This is easily remedied by painting.

Brass is generally satisfactory when adequately nickel plated. Tin plate is also satisfactory, but is less resistant to mechanical damage. Silicon-bronze and beryllium-copper are moderately satisfactory without subsequent finish, showing only tarnish under humidity conditions. Under salt spray they corrode similarly to other copper alloys. Nickel plate will provide protection.

No finish schedule investigated is considered acceptable for zinc die castings. The most satisfactory schedule comprises an immersion chromate finish followed by a baked primer and a baked topcoat. Unlike metal contacts are a source of difficulty.

Magnesium is satisfactory when chromate treatment, such as Dow No. 7, followed by a primer and topcoat is used. Because of electrolysis, extreme care must be taken when magnesium is used with dissimilar metal contacts.

Nonmetallic materials are also seriously affected by variations in temperature and relative humidity. Many such materials were subjected to the same cycles of temperature and humidity as previously described for nonferrous and ferrous metals. The performance of these nonmetallic materials, when tested, varied widely but all showed extreme dimensional instability.

Untreated paper, because of extreme dimensional instability and disintegration under high humidities, cannot be used in designs for severe service conditions. Treated papers must be thoroughly impregnated. Vulcanized fiber proved slightly better than paper, but its lack of dimensional stability made it unfit for use in high humidity. Leather showed very poor dimensional stability and, according to the type of leather used, the other physical properties fluctuated widely. Some types became soft and pulpy. Others became hard and brittle.

Little difficulty was experienced with either cloth- or paper-based phenolic laminates of high quality. Low-resin-content, paper-based laminates blistered and delaminated. Low pressure polyester resin laminates and melamine-glass cloth laminates withstood high humidity very well.

Conventional phenolic molding compounds were subjected to dimensional changes caused by moisture absorption. These changes caused binding or cracking of assembled parts. Fumes given off by these materials at high humidities and temperatures caused corrosion of cadmium-chromated parts and accelerated the corrosion of many other metals. The use of a special cotton-filled, wet, mixed phenolic compound greatly reduced these difficulties.

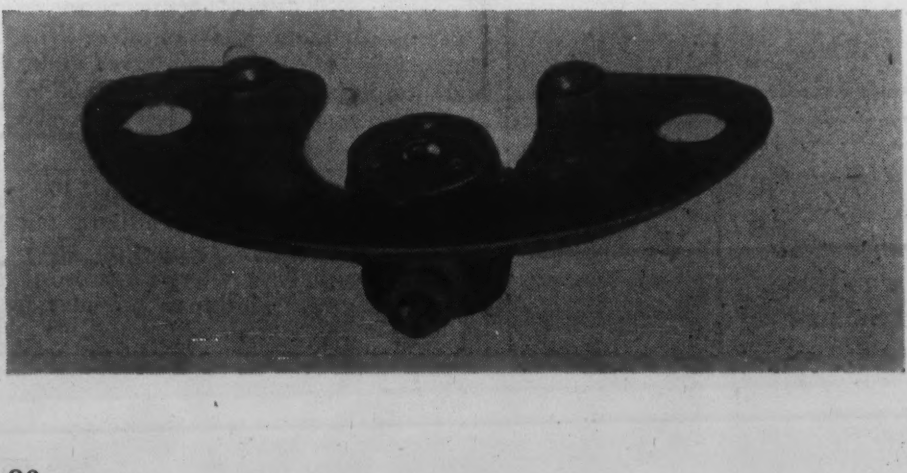
The high humidities often caused electrical leakage with ceramics. A coating of silicone, G-E Dri-film, usually eliminated this difficulty.

Fungus Problems

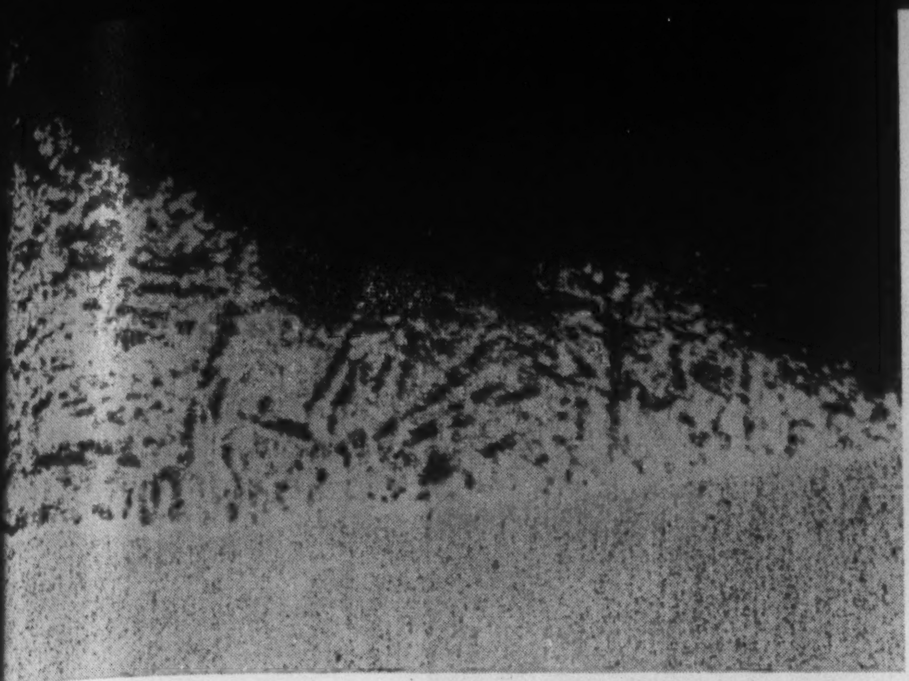
When the Armed Services Tropicalization program was launched, the major portion of the emphasis was placed on fungus-resistance. As a result, many requests were made for instruments having all possible parts coated with an approved fungus-resistant varnish. Such coatings of varnish invariably caused difficulty because of blistering and peeling. Extensive investigations of the problem showed that, in instrumentation, fungus growth was an insignificant problem in comparison with corrosion. Under humidities sufficiently high to encourage fungus growth, instruments were first damaged by corrosion.

No coating material, such as a fungicide varnish, was effective for the protection of instruments. In general, such stop-gap methods caused more difficulties than they corrected.

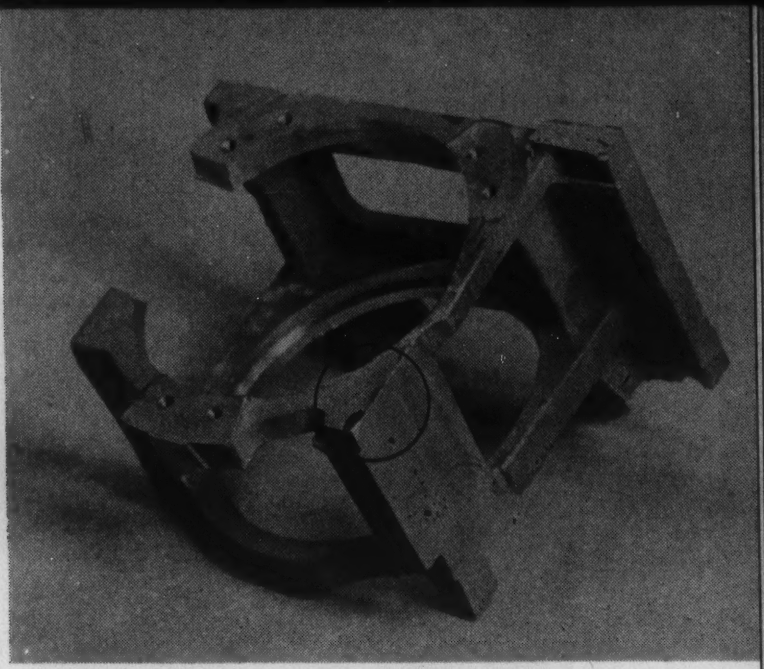
Editor's Note: The authors wish to acknowledge the assistance of Mr. J. M. Whittenton, Instrument Engineering Div., General Electric Co., West Lynn, Mass.



Subassemblies with complicated contours are difficult to plate with coatings that are free from porosity.



Photomicrograph showing fillet of Alsoco solder on aluminum base metal, after 250-hr. salt spray test. (100 X magnification).



The circle indicates where a rupture in this aluminum casting was repaired by soldering. The soldered joint was machined to a smooth surface.

An Aluminum Solder That Requires No Flux

—New Material Preview

One of the chief drawbacks to the extended use of aluminum, particularly for electrical applications, has been the lack of a simple, satisfactory method of soldering this material to other aluminum parts and to brass and copper fittings. Now there is available an aluminum solder which can be applied without fluxes and which is being investigated widely by those companies making and distributing electrically conductive aluminum wire and by the principal aluminum producers. Thus far, it has been tested and proved satisfactory for use with 2S, 3S and 52S aluminum, and is expected to work well with other heat-treatable aluminum alloys.

The new solder, known as Alsoco, was developed for the Swiss army and is now being made in this country and distributed by Aluminum Solder Corp., 10 E. 52nd St., New York. The solder comes in three analyses, with melting points from 425 to 725 F, with the lowest melting point type used for joining thin, delicate parts.

Another promising use for Alsoco is in the repair of broken or otherwise defective aluminum castings. Repairs made in castings with M-1001 Alsoco (melting point 728 F) are sound and machinable.

There are three grades of the new solder, M-1001, M-1002 and M-1003, with melting points of 728, 680 and 425 F, respectively. M-1001 is intended for use in repairing aluminum die castings, heavy sheet and heavy extruded shapes. M-1002 is used for thin aluminum sheet, heavy electrical wiring and soldering light extruded shapes. M-1003 serves to join foils, light joints and light electric wiring.

Uses of aluminum are expected to increase through use of this solder, developed by the Swiss, which has good properties and is easy to use.

Test Results

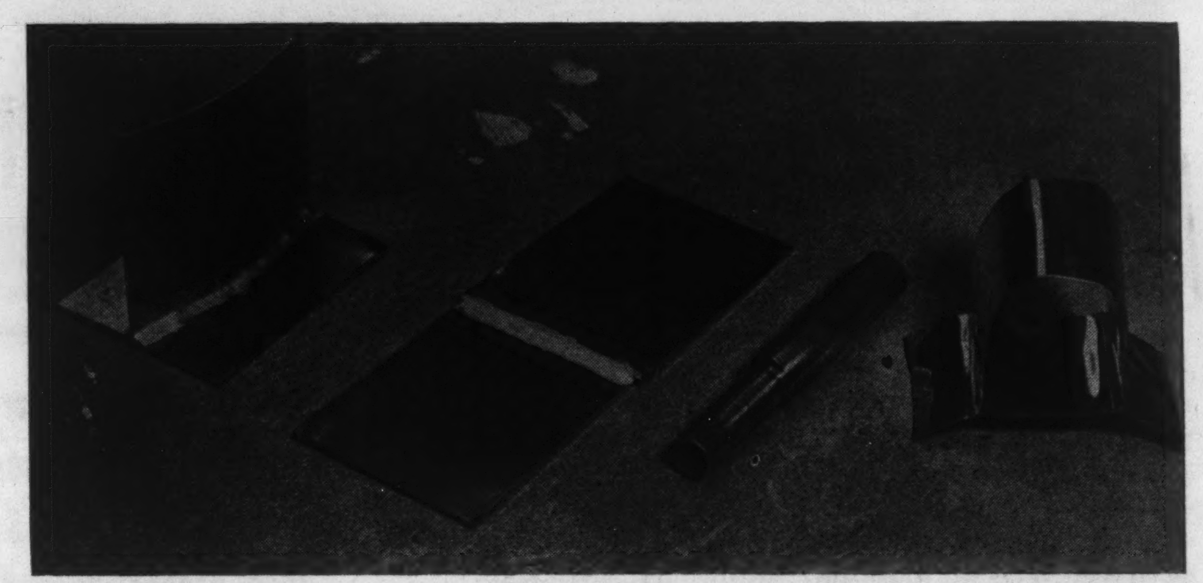
Many properties of the solder have already been investigated by an independent testing laboratory (New York Testing Laboratories, Inc.), and other tests are now being made. Tests covered melting properties, soldering operation, shear tests, electrical resistance, effect of vibration, and a preliminary of corrosion.

All tests were conducted on joints between two pieces of 3S½ H aluminum alloy, and between this metal and one-half hard Muntz metal (60 copper, 40% zinc).

In shear tests 0.064 in. by 1 in. by 6 in. strips were used, with the strips joined by 1-in. overlapped joints. Solder M-1001 was used. With maximum loads from 980 lb. and 1,020 lb. on aluminum joints (before salt spray exposure) the parent metal broke 1 in. and 1½ in. from the joints, respectively. After a salt spray exposure of 250 hr. a similar specimen broke in the base metal at the edge of the joint under 970-lb. load.

In an aluminum to brass joint one test resulted in the specimen shearing through the joint under 650-lb.

Samples of soldered aluminum joints for electrical applications.



Here are shown some typical joints in aluminum parts soldered with the new fluxless solder.

load; another under 980-lb. load sheared through the aluminum ½ in. from the joint. After 250-hr. salt spray exposure shearing took place in the joint under 340-lb. load.

The shear values of aluminum-to-brass joints varied considerably, probably due to variances in solder applying techniques.

Salt spray tests showed a reduction in joint strength of from 3.0 to 8.6% in aluminum joints and from 19.8 to 58.3% in aluminum-to-brass joints.

In vibration tests all results indicate that the soldered joints will withstand vibration better than the wires being joined.

Preliminary investigations of the corrosion properties of the solder have been made. Metallographic examination after 250-hr. salt spray tests showed no preferential attack from the base metal in any of the joints. The solder showed surface corrosion which did not seem to have been caused by galvanic action.

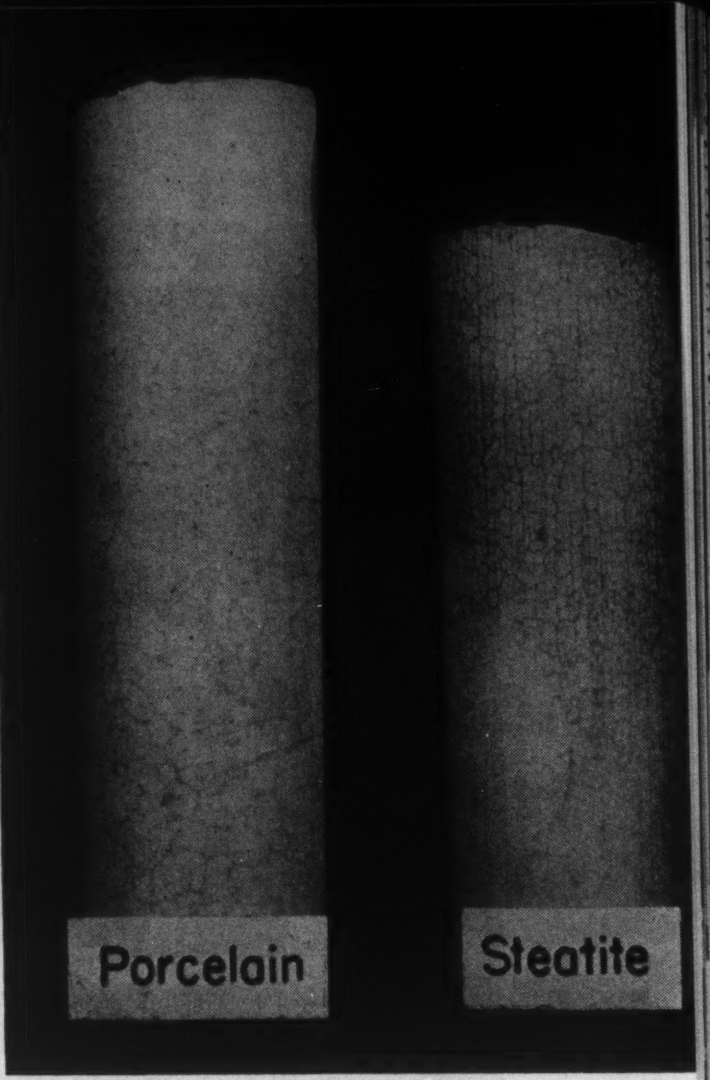
In soldering aluminum wires, decrease in conductivity is of almost negligible value. Resistivity per joint is in the nature of 20 microhms, with an increase of about 40% after a 250-hr. salt spray test.

Methods of Application

Work to be joined by Alsoco aluminum solder is cleaned by conventional methods. The material is preheated, preferably by oxyacetylene torch, and then tinned by rubbing the stick solder over the joint area while that area is being heated to the solder's flow point. Next the pieces of metal being joined are placed in final position and heat applied until the solder flows. Simultaneously, the operator places a bead or fillet at the lap seams. The soldered joint then is permitted to cool to room temperature. No cleaning is required after the joint is completed. If desired, joints can be machined, filed or buffed.

In joining wires to lugs, the wire strands are tinned by dipping and twirling in molten solder.

Since the solder has not been available to industry in this country for very long, little is known as to its range of application, but it is expected to find considerable use in electrical wiring, aluminum casting repair, and in production applications where aluminum is used in business machines, electrical appliances and communications equipment.



Cracking of the tubes was a result of thermal shock. Tubes were heated to 375 C for 30 min. and then plunged into ice water.

Materials for Wire-Wound Resistors—Some Recent Developments

by EDWARD E. MARBAKER, *The O. Hommel Company Senior Fellow, Mellon Institute of Industrial Research*

> **Silicone coatings were found to be most satisfactory for resistance units which had to withstand diverse and destructive heat and atmospheric conditions.**

The developments described resulted from a research program recommended by the OPRD of the War Production Board, carried out during a 2-year period under a contract with the O. Hommel Co., Pittsburgh. Under terms of the contract, personnel and facilities of the multiple fellowship sustained by that organization in Mellon Institute were augmented and devoted exclusively to the search for a solution to the resistor-coating problem.

RESISTORS ARE IMPORTANT COMPONENTS of electrical and electronic circuits, used for the purpose of regulating the current under a given voltage load. While there are many types of resistors, this article is concerned with the form which consists of a ceramic or other insulating core wound with resistance wire, the ends of which are attached to band and tab or ferrule terminals. The wire of such resistors must be protected from mechanical damage and from moisture and other atmospheric influences by the application of a coating having suitable strength and other desirable properties but which must not interfere with the heat dissipation of the unit.

Wire-wound resistors used in Army and Navy communications equipment, operating at relatively high temperatures, often under very diverse and harmful atmospheric conditions, require coatings of greater ruggedness than those generally applied to resistors for ordinary commercial use. To insure the procurement of resistors of the highest quality, the

Glass-coated Kovar-wound resistors showed no electrical leakage after nine cycles of thermal shock.

Army and Navy have set up, in an official joint specification JAN-R-26 and its amendments, a series of simulative qualification tests, designed to insure the best possible performance under the most adverse conditions. These tests are based on the determination of resistance to thermal shock and the extent of subsequent penetration of moisture. The resistors intended for the most severe service are designated as Grade 1 Class 1, and are described as "most resistant to salt water immersion following thermal shock in water" and to be "suitable for continuous operation at a maximum temperature of 275 C".

The coating for resistors most generally employed is vitreous enamel, which is applied to the wound tubes in the form of a clay-suspended slip, dried and then fired at temperatures ranging from 1250 to 1550 F, usually in continuous furnaces. The resulting coating is adherent and has a smooth glassy surface. Unfortunately, commercial resistors of this type lacked the necessary properties for successful use by the Army and Navy during the war and the number of replacements required was so great that production could not keep pace with the demand. A measure of relief was attained by the use of a hermetically-sealed glass-enclosed resistor, but the employment of this type was limited by not too high mechanical strength and the fact that it could be supplied only with ferrule terminals.

The principal cause of failure of enameled resistors was attributed to the tendency of the enamel to break down in thermal shock, although it was suspected that the similar failure of the ceramic insulating cores which were open at the ends might also occur.

Vitreous Enamel Coatings

When the enamel coatings of some commercial resistors are examined under a low-power microscope the surface appears to be marked off into polygonal areas by many fine cracks, and such resistors are subject to penetration of moisture and ultimate failure by wire corrosion.

It is a well known fact that such "crazing" or "peeling" is caused by differential expansion or contraction of the enamel or glaze and the body to which it is applied. The problem, therefore, was to match the enamel to the resistor system so closely that neither crazing nor peeling could occur even under severe thermal shock. The fact should not be overlooked, however, that the effects of differential expansion or contraction are modified by the elasticity, tensile strength, and heat conductivity of the enamel—qualities which can be varied only within very narrow limits.

The great difficulty in achieving a satisfactory enamel, especially for resistors made of long lengths of closely wound fine wire, lies in the fact that the enamel does not actually come in contact with the tube; hence, the relation between the expansivities of the enamel and the wire becomes very important.

The expansivity of nickel-chromium wire, which is most commonly used, is 17 x 10^{-6}, and of steatite, the most generally utilized insulator material, 8 x 10^{-6}. It is obvious that an enamel that fits the closely wound wire will craze on the tube alone, and that an enamel fitting the tube will peel on the wire. Therefore, at best a resistor enamel must bridge a wide difference in expansivity and this condition must be surmounted in order satisfactorily to coat resistors, especially those of high wattage. It was for a long time held by manufacturers that to make a 50,000-ohm resistor to pass the Army and Navy specification was a practical impossibility.

Another difficulty arises during the enameling process because of the difference between the expansivity of the tube and of the wire. In heating, the wire expands more than the tube and rises appreciably from the surface of the latter. The wire, now unsupported, is wet by the melting enamel, which, because of its surface tension, pulls several turns of wire together, leaving some areas of the tube surface bare. Owing to this wire-bunching, one or more additional coatings of enamel must be applied. The individual turns of wire are usually well insulated by the enamel, but if not local short circuiting will occur and the resistance of the unit will change.

Obviously this phenomenon can best be prevented by using wire and tubes of similar expansivity. Unfortunately, tubes having high coefficients of expansion are not sufficiently resistant to thermal shock, and wire of as low expansivity as the tube has too high a thermal coefficient of resistance—that is, the change in resistance with temperature is too great for satisfactory service.

Steatite and electrical porcelain tubes "crackle" when subjected to thermal shock. In such cases the surface tends to be covered with tiny surface cracks and the areas bounded by these cracks become larger as the expansivity of the tube decreases. By repeated subjection to thermal shock, crackling increases to the point where actual cracks are formed. The tube thus loses strength and the possibility of moisture penetration is increased.

It is obvious, too, that the body of the tube should have a very low porosity, as measured by its ability to absorb water. Highly vitrified tubes are less resistant to thermal shock than those having some degree of porosity—a condition which adds to the difficulty encountered in making a fully satisfactory resistor. A cracked or porous tube can be quite as detrimental to resistor performance as a defective enamel coating.

Very dense tubes of zircon porcelain or cordierite are lower in expansivity than steatite or electrical porcelain; if, however, they are wound with nickel-chromium wire, the tendency of the wire to leave the tube during enameling is increased. Wires of somewhat lower expansivity than nickel-chromium are available, but they have undesirable electrical characteristics.

In spite of all the difficulties to which reference has been made, some enamels were developed which showed a degree of promise.

In the course of the research, two types of resistors having elements of approximately equal expansivity were devised. In the first contrivance, a pre-enameled steel tube having a coefficient of expansion of 14 x 10^{-6} was used as the insulating core upon which nickel-chromium wire was wound. The elements of this system have approximately the same expansivity at a high level.

After enameling, the ends of the wire were embedded in silver lacquer and the copper terminal bands applied so that contact was made through the silver. Although two resistors of this type failed by breakdown of the ground coat, it was still believed that an enameled steel tube resistor could be accomplished.

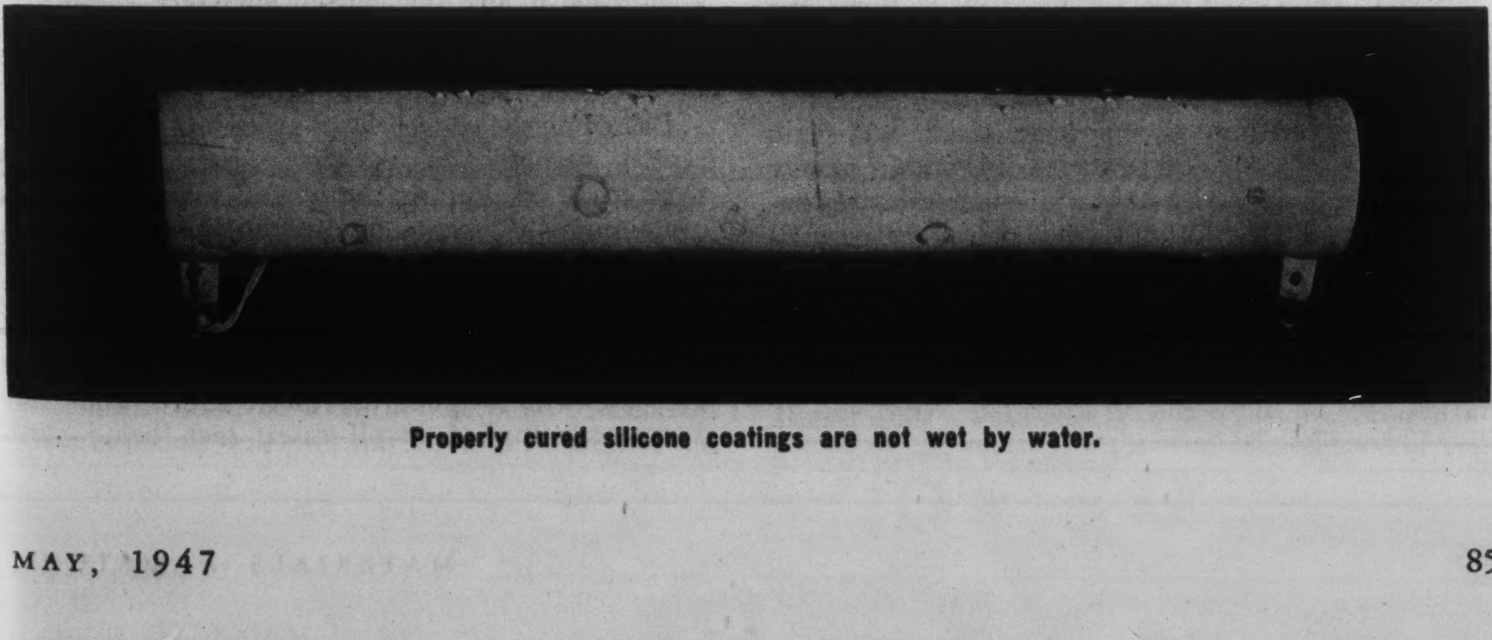
The second type of resistor consisting of elements having closely approximating expansivities was made from a zircon porcelain tube having a coefficient of expansion of 4.3 x 10^{-6}, wound with Kovar wire (6 x 10^{-6}), and coated with an enamel made from Pyrex glass (3.15 x 10^{-6}). Specially designed terminals of Kovar wire were used. (Kovar is an alloy of iron, nickel, cobalt and manganese.) Although such resistors passed the qualification tests for resistance to thermal shock and moisture penetration, they were unsatisfactory electrically because Kovar wire has a low specific resistance, and, in common with all alloys of low thermal expansivity, its thermal coefficient of resistance is high, 0.040% per deg. C. The upper limit allowed in the specification is 0.026% per deg. C.

As a result of the work with resistors of the three types just described, the outstanding conclusion is that, to produce a Grade 1 Class I resistor, elements of closely agreeing expansivity are necessary. But combinations which work well from one standpoint are unsatisfactory from another. Thus, if a ceramic tube of high expansivity and a high degree of resistance to thermal shock, or a resistance wire having a high specific resistance, low thermal expansivity and low thermal coefficient of resistance, were available, the construction of resistors of outstanding qualities would be relatively easy to attain. However, at the time the most desirable properties of ceramic tubes and resistance wires appeared to be mutually exclusive, and the problem had to be approached from another direction.

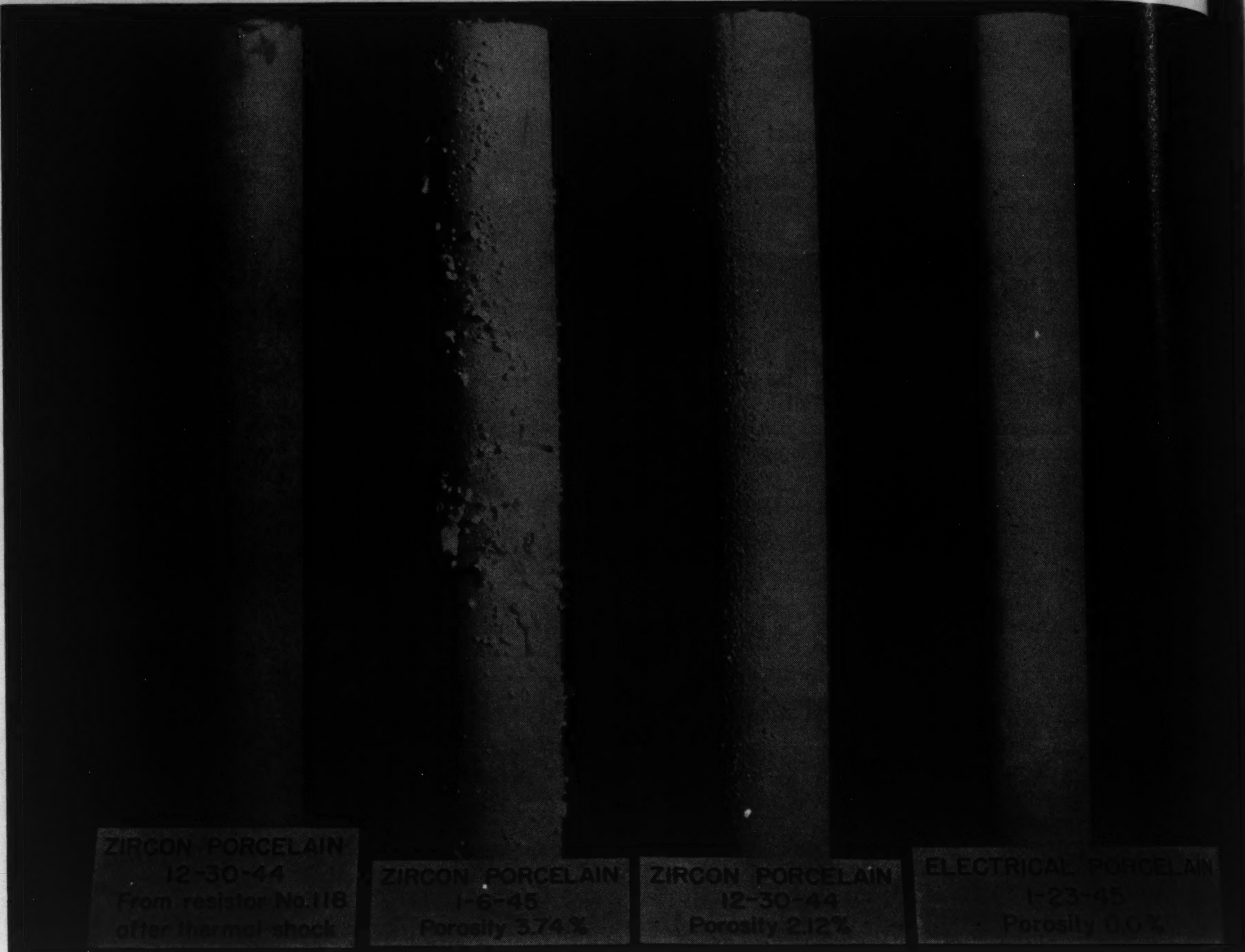
Silicone Coatings

The silicones constitute a new class of compounds comparable in many respects to the organic plastics, which are polymerized ring or chain structures built around carbon atoms. In the silicones the central atoms are silicon and with them are combined the oxygen and organic groups which give the compounds their special properties. These compounds after polymerization have a high degree of thermal stability as evidenced by the fact that they are unaffected by operating temperatures as high as 300 C and as low as −40 C. After curing, the silicone used in this work is very elastic, and in many respects it resembles rubber. It is quite impervious to water, in fact, water does not wet it; it is chemically inert; and it possesses a high dielectric strength.

Working cooperatively with the multiple fellow-



Properly cured silicone coatings are not wet by water.



This illustration shows the effect of salt water on uncoated tubes.

ship of Corning Glass Works which, under the leadership of McGregor[1], was responsible to a considerable degree for the development of the silicone product used in this work[2], a large number of resistors were produced and tested. Before curing, this material has the appearance and consistency of heavy white paint. As such, it can be easily applied to tubes wound with resistance wire. Its heat treatment or curing is accomplished by the use of temperatures from 250 to 375 C over commercially feasible time intervals. After curing, the coating is smooth, free from tackiness, and relatively hard, although the hardness is much less than that of enamel and some care in handling is necessary to avoid abrasion.

It has been mentioned in reference to enamel coatings that expansivity is important, and it was plain that their elasticity could be varied only within narrow limits. The expansivity of the silicone resin by contrast is very high (160×10^{-6}), but this property is not significant because the elasticity is also of a high order, so much so that it is independent of the expansivities of tube, wire and terminals as used in resistor construction. At the lower curing temperatures, moreover, wire bunching does not occur to any appreciable extent even where nickel-chromium wire is wound on cordierite tubes, a combination which represents the greatest difference in expansivity.

In the prosecution of the work with the silicones after the preliminary experiments, all units were made by winding 2.5-mil nickel-chromium wire on tubes 8⅝ in. long and 1⅛ in. outside dia. in order to have a resistance of 50,000 ohms, the standard for test under Specification JAN-R-26.

Application of the Silicones to Resistors

Unless great care is taken to apply the silicone paste in thin coats, blistering will take place during curing.

Following the conventional procedure of enameled-resistor manufacture, the first satisfactory resistors were made by dipping the wound tubes in a slurry containing 45% paste in carbon tetrachloride. But the dipping process is time-consuming and requires considerable amounts of material and careful control of the viscosity of the slurry. Since this silicone has a paint-like consistency, it can be rubbed out evenly over the wire without too much effort. Four thin coats were applied in all cases, each being cured

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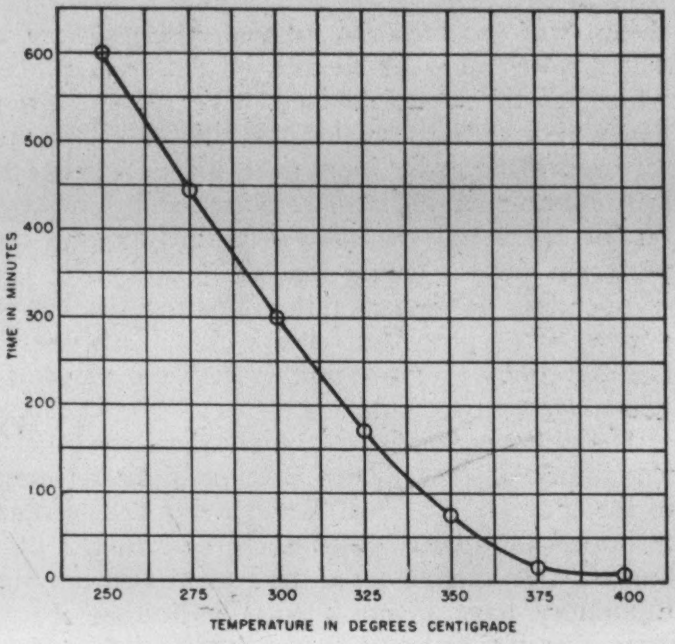
[1] R. R. McGregor, Corning Glass Works Senior Fellow at Mellon Institute.
[2] Dow-Corning Silastic SC-75.



Relationship of curing time to temperature for a silicone coating.

separately. One coat is insufficient to protect the wire completely, two coats are not quite satisfactory, three coats are adequate, but the fourth coat was added to correct any possible unevenness in thickness.

It has been found good practice to bevel the edges of the terminal bands, to apply the silicone to them before placing them on the tubes, and to bake it at 250 C for 1 hr. or at 400 C for 4 min. before winding.

More than 250 resistors were coated by this method with satisfactory results. Compared with the dipping method, it is more economical from the standpoint of time and material. Dipped coatings were 15 to 18 mils thick and weighed about 30 gm., while rubbed coatings, 8 to 10 mils thick, averaged about 8 gm. The rubbed coating, although still not completely resistant to abrasion, was much harder than the dipped coating.

After application to a resistor, the silicone layer resembled a coat of wet paint and did not dry at room temperature, and it was therefore necessary to work in a room free from dirt and dust. In curing, the coating behaved like paint in drying. It went through a tacky stage, the tackiness decreasing with increase of time until the completely cured coating was dry and relatively hard. It was found that intermediate coats need not be completely free from tackiness, and therefore their curing time was shorter than that of the final coat.

The resistors made in the laboratory were cured as follows: the first three coats at 250 C for 1 hr., and the last coat at 250 C for 16 hr.; the last step of this schedule covers an overnight period, used only for convenience.

The effect of higher curing temperatures was studied. Heated at 325, 350, 375 and 400 C for 1 hr., the best result was obtained at 350 C. Above 400, the coating appeared to lose its rubbery resiliency and its surface became somewhat powdery, but this condition had little or no effect on its water repellency. Tackiness decreased as the temperature increased. When heated for 15 min. at 400 C, the coating lost some of its resiliency; at this temperature, however, excellent results were achieved by reducing the time to 8 min.

The curing of coatings in commercial enamel-firing equipment was considered. Furnaces of two types are in general use. Since the box-type furnace closely resembles the oven and the furnace that were employed in the present work, it appeared that it might be used without difficulty by merely setting it for the proper curing temperature. The continuous furnace offers a more serious problem because the speed of the conveyor belt, the nature of the thermostatic control, and the position of the thermocouple with respect to the moving load must be taken into account. A different curing schedule will probably have to be worked out for each continuous furnace, although theoretically it will be necessary only to control the temperature and time in the hot zone of the furnace. The problem is simplified by the fact that coatings can be cured at temperatures higher than those used in making resistors in the laboratory and in less time.

Valuating of Resistors for Grade 1 Class I Requirements

A large number of resistors made with all kinds of tubes available and curing the silicone coating at 375 C for 15 min. were tested in accordance with the methods of the JAN specification, both in the author's laboratory and at the Naval Research Laboratory. A recapitulation of the results is set forth in the following table:

Tube Material	*Tested*	*Passed*	*Passed (%)*
Steatite	30	23	76.3
High Alumina	10	9	90.0
Electrical Porcelain	26	23	88.6
Zircon Porcelain	40	36	90.0
Glass	9	9	100.0
Cordierite	31	25	80.7
Steel (Pre-Enameled)	13	7	53.8
Total	159	132	83.0

An important advantage of the silicone coating lies in the fact that it can be removed easily from a failed resistor and the cause of failure determined. Some resistors which have completed nine cycles later have shown open circuits because of cracks in the tubes through which salt water had penetrated to the wire and caused corrosion. An excellent example of the first case was revealed by a resistor having a dipped coating which was dissected from the wire and tube in one piece. No mark of rust could be seen on the inside of the coating, yet a well-defined spot of corrosion was observed. In general, failures were associated with tubes of steatite or electrical porcelain which, of the materials used, have the greatest tendency to crack in thermal shock, although some manufacturers make better tubes in this respect than others.

A number of failures were caused by seepage of salt water through the walls of porous tubes of zircon porcelain (water absorption, 2.1% and 3.7%) and, in one case, of high alumina. Coating the inside of porous zircon porcelain tubes with the silicone paste counteracted, to some extent at least, the effect of the relatively open structure.

The rubbery consistency, high elasticity, and nonwettability of the silicone coating make it immune to the ordinary effects of thermal shock. The coating is impervious to water as such, and results of the humidity test carried out at the Fort Monmouth Signal Laboratory have given a good indication that the coating is also resistant to the more subtle attack of atmospheric moisture. The cured coating appears to undergo little or no change in structure or properties at the temperature at which Class I resistors are operated. This property was checked rigorously by a 1000-hr. life test.

The resistance to abrasion of silicone coatings is naturally less than that of vitreous enamels. On curing at 375 C, however, sufficient strength is developed, although some care in handling the resistors must be exercised. In view of their superior quality with respect to resistance to thermal shock and moisture penetration, this precaution should not be considered unreasonable.

Tubes of six different materials were used as resistor cores with a considerable variation in results which appear to be due to the characteristics of the tubes or wire rather than to any defect of the coating. In none of the examinations of failed resistors did the coating appear to have been directly the cause of failure.

Since ceramic tubes are used as cores for enameled resistors, many of the failures, which in the past have been attributed to faulty enamel coatings, must have been due actually to porosity or to break-down of the tubes because of their inability to withstand severe thermal shock. Thus, the corrosion of the wire took place from the inside of the tube instead of the outside as assumed in the specifications. The possibility of such a condition was indicated at the very outset of this project, but it was not until the use of the silicone coating made possible examination after failure that its actual occurrence could be observed.

The performance of resistors is as much a function of the tube as of the coating, and, therefore, it is important to note that the materials with the highest rating are glass, zircon porcelain, and high alumina. Electrical porcelain tubes have a slightly lower rating. The results shown by resistors made on cordierite tubes were misleading because some of the coatings were cured at 375 or 400 C, and cracking of the latter, caused by wire rising, took place. In the salt water immersion test, however, the earliest failure occurred in the seventh cycle. The rating of cordierite resistors, with coatings cured at 250 C, was 84.5%. Steatite-cored resistors displayed a rather spotty performance; but with well made tubes, such resistors should give reasonably good service.

In the past, in dealing with enameled resistors, too little attention has been given to the quality of the ceramic tubes used as cores. The specifications call for water absorption of less than 0.1%, but this compliance can be attained only with a highly vitrified body which, in turn, is likely to have less resistance to thermal shock than porous bodies of the same composition. To counteract the latter, some makers have tended to increase the porosity to a slight extent. Even a low degree of porosity can be dangerous, as exemplified by the behavior of the resistors cored with porous zircon porcelain tubes.

The porosity of such tubes can be overcome by the careful application of the silicone coating to the inside surface, and this method may have some significance from the point of view of taking advantage of porosity to secure better resistance to thermal shock.

Conclusion

Silicone resistor coatings are satisfactory in themselves, and the performance of the resistor to which they are applied depends on the material and quality of the tubes and on the freedom of the wire from defects.

The expansivity of the tube material is without significance because of the high elasticity of the coating, provided the tube itself can inherently withstand thermal shock. Equally good results have thus been obtained with cordierite, glass, high alumina, zircon porcelain, and electrical porcelain, all of which are lower in expansivity than steatite and all of which have better resistance to thermal shock. The rising of the wire from tubes of low expansivity, such as cordierite, glass or zircon porcelain, may cause cracking of coatings if they are cured at 400 C for more than 8 min.

The requirement of very low water absorption (porosity) of tubes is as necessary where the silicone coatings are to be used as with enamels unless the additional operation of coating the inside of the tube is to be introduced.

Tubes of any kind should be tested for porosity and resistance to thermal shock by the resistor manufacturer before they are accepted for winding and coating.

A sufficient number of resistors, coated with a silicone paste, have been successfully tested both at Mellon Institute and at the Naval Research Laboratory, to justify the conclusion that such resistors, made in commercial production, should meet the Grade 1 Class I qualification tests of the Navy Specification for resistance to thermal shock and moisture penetration.

Under peace-time conditions, it is doubtful that resistors of the quality of Grade 1 Class I offer sufficient advantage to offset the higher cost and the great care which must be exercised in their production. It is quite possible, however, that needs for resistors of high quality may later arise, or that coatings may be required for other types of electronic equipment, such as capacitors. In these cases, silicones of the silastic type can be recommended as coating materials.

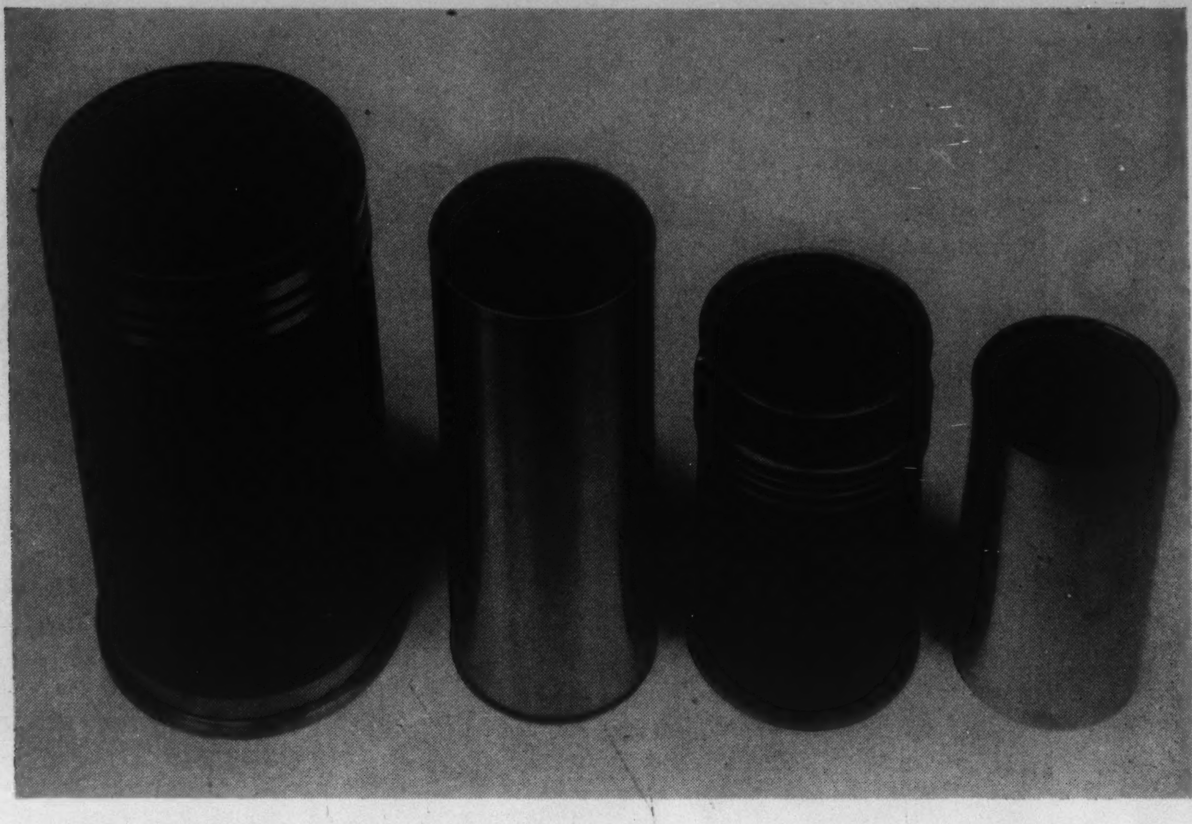


Fig. 1—A group of cast alloy iron cylinder liners which has been heat treated by means of the isothermal method.

Austempered Cast Iron Serves as Cylinder Liners

by C. W. OHLY, *Chief Engineer, Special Products Div., Thompson Products, Inc.*

AN INTERESTING PRACTICAL APPLICATION of S-curves and time-temperature-transformation (TTT) curves is in the treatment of alloy cast iron cylinder liners for automotive engines, both gas and diesel. Adoption of the austempering method of heat treating the cylinder liners has resulted in several manufacturing economies and longer liner life in heavy duty service.

Minimum distortion, no decarb and uniform hardness are claimed in using salt baths for heat treating thin-walled cylindrical alloy iron parts.

Hardened liners were first used successfully by General Motors approximately ten years ago, and since that time their popularity has increased, and successful application can be found in heavy-duty truck and bus engines throughout the automotive industry. From those close to the cylinder liner business come field reports that hardened cast iron liners give 2½ to 3 times the mileage obtained with a soft liner or with the cylinder block wall itself. The superior wearing properties of the surface when hardened have improved the life of the piston rings and pistons in contact with this surface, making costly engine overhauls less frequent. The future of this product looks excellent in view of past results, and the interest now being shown toward cylinder blocks made of materials other than cast iron makes the future of iron liners even brighter. As manufacturing methods are further improved, making additional cost reductions in this commodity possible, many more applications will be made.

The problems with which the heat treater is con-

Fig. 2—Typical microstructure of alloy iron used when oil quenched and drawn to 450 to 480 Brinell.

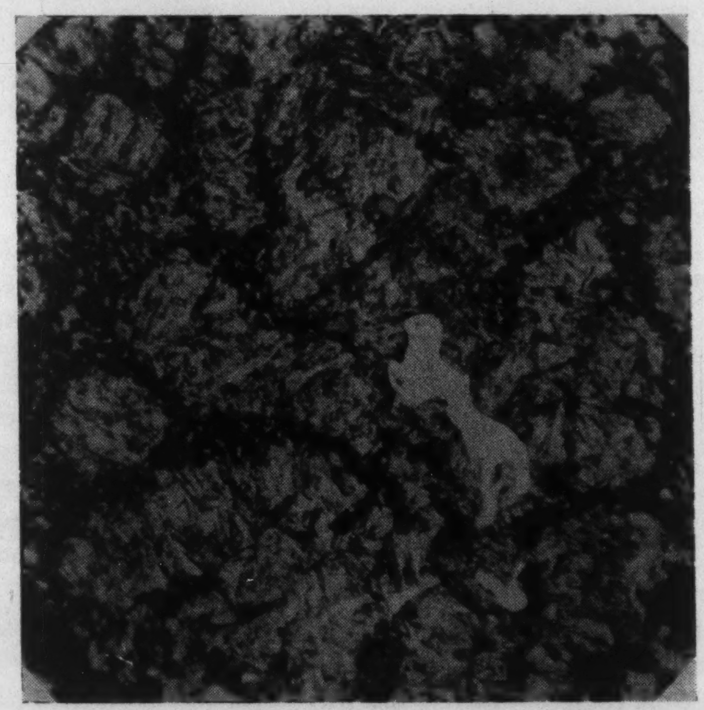


Fig. 3—Microstructure of alloy in Fig. 2 when austempered to a similar Brinell hardness.

fronted in processing cylinder liners seem ones most easily surmounted if full use of the knowledge of isothermal heat treatment is made. These involve the securing of:

1. Minimum amount of distortion in quenching, thereby minimizing stock necessary to remove in finishing the liner.
2. A uniformly hard liner free from high stresses which would adversely affect the liner's performance.
3. Complete absence of surface decarburization in any degree.

The solution to all three of these problems seemed to lay in working out a proper isothermal treatment. To review briefly, austempering consists of quenching steel or cast iron in a constant temperature salt bath held somewhere above the Ms point of the material and below "the knee" of the S-curve. The exact temperature of the bath is, of course, dependent upon the material analysis, the time required for the transformation to take place at a given temperature, and the physical properties desired of the part. Laboratory results, as well as production records on other commodities processed by this method, indicated reduction in non-uniform volume changes, minimum distortion and elimination of high stresses, and improved physical properties superior to those obtained by the conventional heat treating method.

The average analysis of the iron used by Thompson Products, Inc., in the manufacturing of hardened liners is as follows:

Total Carbon	3.10 to 3.45
Combined	0.60 max.
Silicon	1.95 to 2.35
Manganese	0.55 to 0.90
Phosphorus	0.25 max.
Sulfur	0.10 max.
Chromium	0.25 to 0.50
Nickel	0.25 to 0.50
Molybdenum	0.25 to 0.50

Although typical TTT-curves were not available for this analysis, its characteristics with respect to hardenability have been found to be somewhat comparable to those of the SAE steels of similar carbon and alloy content, and this data have been used as reference. Fig. 2 shows the typical microstructure of this iron when treated by the conventional oil quench and draw methods to a hardness of 450 to 480 Brinell. It can be noted that the photomicrograph clearly pictures a matrix containing the sharp needle-like structure of primary martensite. Fig. 3 shows the microstructure of the same iron following austempering to a hardness of 450 to 480 Brinell. The matrix structure is bainite, the intermediate structure between martensite and pearlite, which is typical of the microstructure obtained by this method of treatment.

The equipment used in treating these liners was furnished complete by the Ajax Electric Co. and is clearly shown in the accompanying illustrations taken while the unit was in full operation at Thompson Products. Briefly, the equipment consists of a group of four Ajax immersed electrode-heated salt bath furnaces arranged in a line in the following order: preheat, high-heat, quench, stress relief, plus wash and rinse tanks. The entire battery of furnaces and wash and rinse tanks is surmounted by an automatic conveying system approximately 30 ft. in length capable of transferring the sleeves to and from each bath automatically at present intervals and returning them completely washed and rinsed to the loading station. A single operator can easily load and unload these sleeves at a production rate varying from 35 to 75 liners per hr., depending upon the size and weight, and has ample time to spot check the liners for hardness. Samples of typical sleeves treated in this

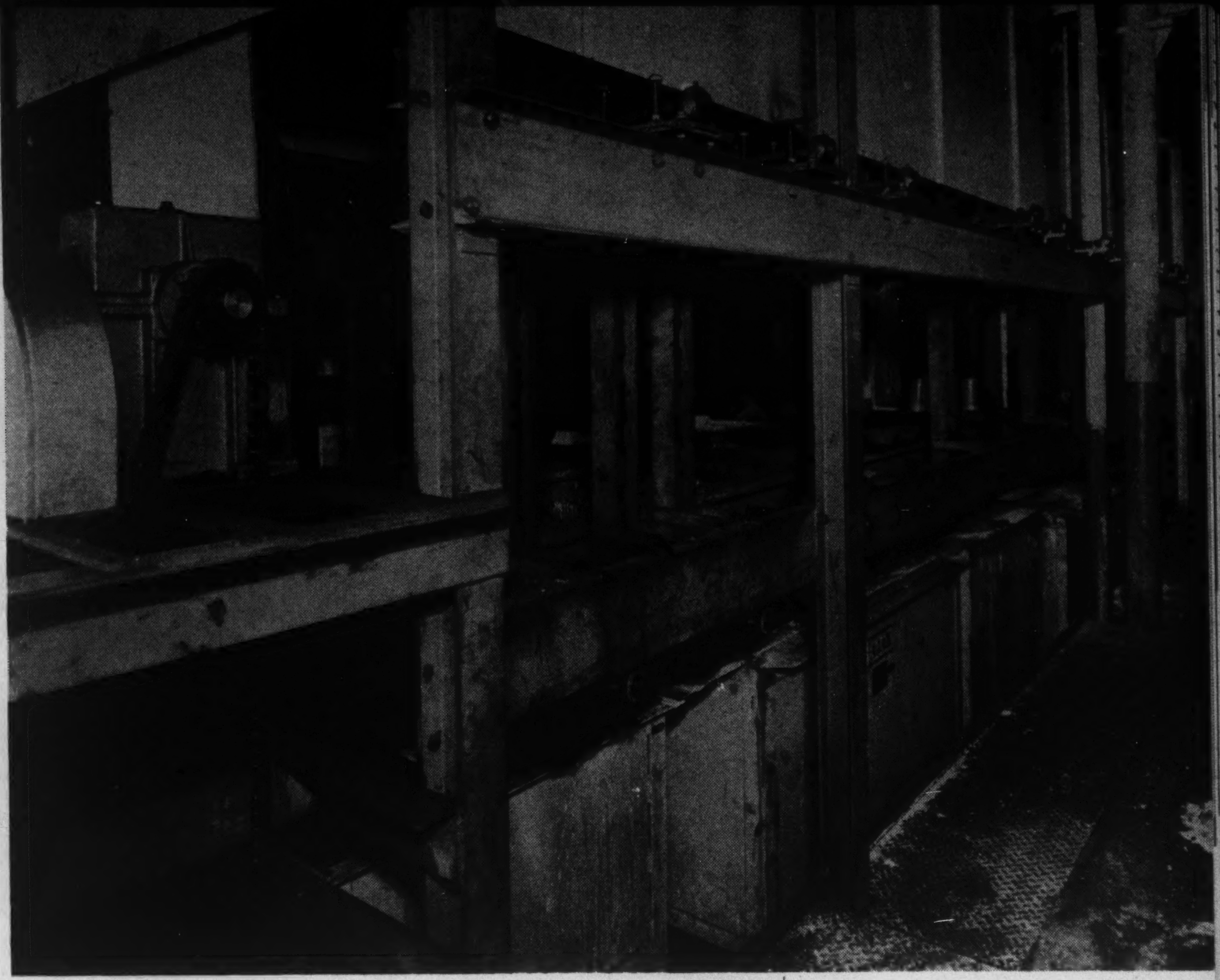


Fig. 4—Furnace arrangement at Thompson products for austempering liners. Loading and unloading are done at the far end of the set-up.

manner are shown in Fig. 1. Simple alloy hooks made of ½-in. nickel-chromium rod support the liners in an absolutely vertical position throughout the process and are so designed that no fixture change is required regardless of the physical dimensions of the liner to be treated.

The low temperature pre-heat bath is being used since initial test results indicated that the relief of machining stresses at the lower temperatures resulted in a marked decrease in the amount of distortion. The agitation in the nitrate salt quench bath, which is of prime importance to the success of all isothermal heat treating applications, is achieved by the use of compressed air dispersed at the bottom of the bath plus the use of a motor driven propeller. Proper adjustment of the agitation of this bath determines whether or not the required physical properties will be met with a minimum of distortion. With liners whose wall thickness are as thin as 1/16 in., we find it an advantage to stop all agitation immediately before quenching and renew this agitation after the sleeves are in the bath for a matter of 15 to 20 sec. The control of this intermittent agitation is completely automatic, being synchronized with the conveyor mechanism itself. By mechanically charging and discharging the sleeves at a controlled rate and in an absolutely vertical position, we have obtained a uniformity of hardness and physical properties heretofore found impossible with manual operation.

We have found that this method of treatment enables us to produce cylinder liners whose hardness over the entire surface will remain within a total of three points Rockwell C. The net amount of distortion in the treated sleeves of the dry liner type whose wall thickness measures ⅛ in. ranges from 0.001-in. to about 0.010-in. total indicator reading with the average distortion between 0.003 and 0.004 in. Cylinder liners with wall thicknesses as low as 1/16 in. weighing less than 3 lb., as well as sleeves with wall thicknesses exceeding ⅜ in. weighing above 25 lb., have been treated successfully with results comparable to those noted above with respect to hardness and distortion. Cylinder liners austempered in the equipment herein described can be finished to size after hardening with only honing operations on the inside diameter and grinding of the outside diameter. By our previous hardening method, which consisted of manually oil quenching from a salt bath, the added amount of growth and distortion which occurred made a boring operation on the hardened liner necessary. The added stock allowed in order to clean up all surfaces in the finish also increased the cost of grinding the O.D.

In order to more fully understand and appreciate the advantages gained by austempering liners we have reviewed the actual savings made possible on a liner with a 4⅛-in. bore and a wall thickness of 3/16 in. The hardening process formerly used by Thompson Products consisted of manually handling the liners through two gas-fired salt baths followed by an oil quench and a stress relief draw in a Homo-type furnace. The distortion of the liners ranged from 0.010-in. to 0.020-in. total indicator reading, and with this hardening procedure we increased the labor hours 43% for hardening and finishing the liners. It was necessary that we allow almost 100% more finishing stock than is used at the present time, the removal of which required that we bore the sleeve after hardening—an expensive operation from the standpoint of labor hours and tool costs.

One bank of Ryan spotwelders used in the spot-tacking department to "stitch" stainless steel half-stampings together.

Spotwelding in Aircraft Manufacture

by **FREDERICK S. DEVER,** *Spotwelding Supervisor, Ryan Aeronautical Co.*

SPOTWELDING, AS A MEANS OF FABRICATION, is relatively new in the aircraft industry. It had been used for the joining of non-structural parts and for temporarily holding parts together prior to riveting or fusion welding. Typical examples of these applications at the Ryan Aeronautical Co. are found in the manufacture of engine cowlings and exhaust manifolds.

During the past decade it has grown from a fabricating process, little used except for secondary aircraft structures that were lightly stressed, to a method that is successful in many primary structure applications. This has come about because of the increased knowledge of equipment and its use which has improved the sheer strength and consistency of spotwelds.

The process specifications which basically govern the manufacturing procedures used are those issued by the Army and Navy Procurement Sections. As they were first written, these specifications confined spotwelding to a considerable extent and limited the production applications. This was due to the fact that equipment then available was not completely reliable in that electrical circuits, moving parts and

An increase in the knowledge of spotwelding techniques and results has made this joining method an accepted procedure for primary aircraft structures.

relays demanded constant and careful maintenance. In addition, spotwelding failures were encountered. Therefore, it appeared desirable to make the process prove itself before relaxing requirements.

With the increased use of the method and the accumulation of service data, it was readily foreseen at the Ryan Aeronautical Co. that the technique could be utilized to excellent advantage. It is fast, economical, flexible, and adds no weight to the structure. It is particularly desirable in joining sections where they are exposed to the air stream in aircraft. There is no resultant projection, and the surface exposed can be held to a maximum variation of only 0.004 in.

Indentation can be almost eliminated on one side of the sheet by having a combination of contoured electrodes. The variety of the electrodes which can be used makes the process of spotwelding so flexible that even polished sheet can be spotwelded without seriously affecting its fine finish. Another advantage is that two, three or more sheets can be spotwelded together. This is possible because the spotweld process depends upon the development of maximum resistance at the inner facings of the sheets.

Design

Since the strength of the spotweld must, of necessity, be a shear function, it follows that the design of the parts to be welded can make or break the resultant assembly in so far as satisfactory service operation is concerned. While it is difficult to list any given set of conditions as criterion for good design, the following sugestions, developed at the Ryan Aeronautical Co., should produce desirable results:

(1) Loads to be applied to spotwelds should be shear loads because spotwelds inherently will develop focal points of stress concentration at the edges of the weld and the inner faces of the sheets, if tension or angle loads are applied.

(2) Tension loadings should never be used because the strengths developed in tension are erratic and cannot be relied upon.

(3) Compression loadings are satisfactory providing the design will not allow the spotweld to be placed in tension as a result of a shifting or a movement of this compression loading. An assembly made from light gage material demands special care to assure that the stress does not occur in a plane which will cause buckling, as they may change the spotweld loading from shear to tension.

(4) Ample edge distances must be maintained. This is necessary for two reasons:

(a) To have a sufficient area, over which the pressure can be applied, surrounding the spotweld.

(b) To have an adequate amount of *wrought* material so that the stresses can be carried over and around the cast spotweld metal.

The required edge distance will vary, depending upon the type and thickness of the material. It must be remembered that as the material thickness increases the diameter of the spotweld must be increased to meet the minimum required shear loadings. The spotweld diameters for different metal thicknesses and minimum edge distances are given in charts 1 and 2.

Spotweld patterns (spot groupings) are of great importance in the design of spotweld structures. They are similar to rivet patterns and spacing used to obtain high joint efficiency, and can be divided into three rough classifications:

(1) Single row. In which a single row of spotwelds with a definite center-to-center dimension are used. This joint pattern will require a minimum of overlapping of the sheets. The overlap will be determined by the material thicknesses being used which, in turn, through the minimum shear strengths required, will determine the other dimensions which are spotweld diameter and edge distance. Center to center spacings and joint efficiency graphs are shown in chart 3. These give the recommended dimensions.

(2) Double row. The design requires a greater overlap of material, but the joint efficiency will be from 95 to 100%, if the spotweld spacings given in chart 4 are used. It is often good practice to utilize the double row pattern even though spotweld strengths may be below average minimum. This is due to the fact that this pattern will evenly distribute the loading and result in an assembly giving a longer and more satisfactory service life than a single row of spotwelds of higher average shear values. The double row joint under severe vibration and *fatigue* stress has been found to be more suitable.

(3) Double row staggered. In this pattern the joint

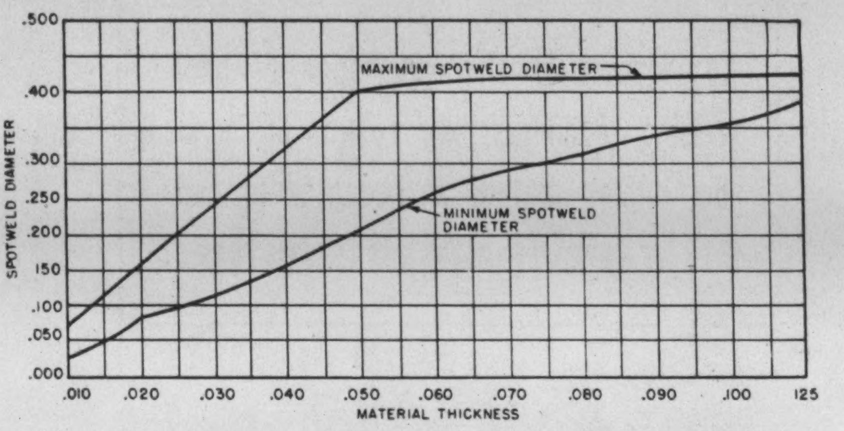


Chart I: Showing the minimum and maximum spotweld diameters for different material thicknesses.

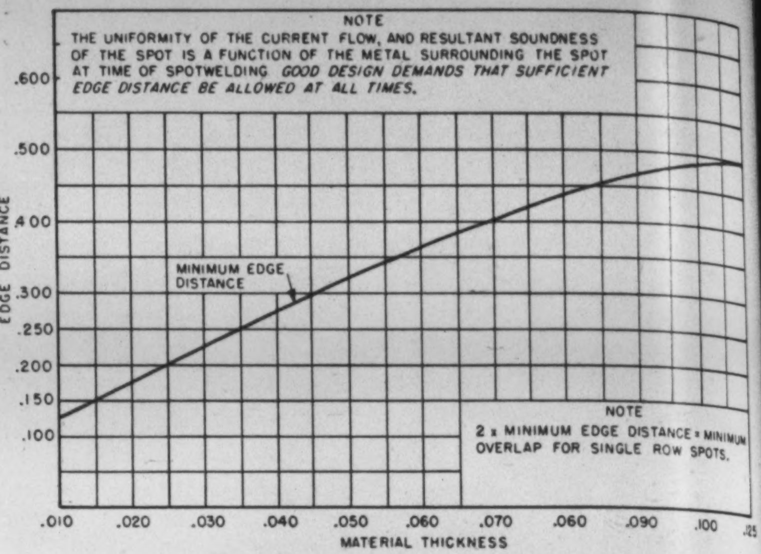


Chart II: Graph of the minimum edge distances for different material thicknesses.

efficiency is approximately equal to the double row pattern. The pattern, however, of the double row staggered is not as well stressed. There is considerable difference of opinion as to which joint is the more efficient for general service usage. The material overlap in the double row staggered is less than in the case of the double row spotwelded joint.

Materials to Be Spotwelded

The materials which can be spotwelded are almost unlimited, although those which develop extreme hardness as a result of heat treatment may present difficulties rendering spotwelding unsuitable. An example of such a material would be X4130 or 4140 steel. Because of the marked reaction of these air hardening steels, with resultant shrinkage and extreme *thermal* stresses, the formation of sound and uniform spots would not be possible. The aluminum alloys and the stainless, low carbon and some other alloy steels all lend themselves to satisfactory spotwelding. There is, however, a marked difference between the treatment of these materials.

Unusual spotwelder which is used at Ryan for reaching highly restricted locations. This "gun" is counterbalanced, air-operated and water-cooled.

The approximate welding current required for 18:8 steels is about 4,750 amp. for two sheets of 0.016-in. material. For two sheets of 0.125-in. material the amperage required is about 13,500. Contrast this with the aluminum alloys in which two sheets of 0.125-in. material will require about 35,000 amp. This difference should be clearly understood because it is on this basis that we can compete and establish the ease with which 18:8 steels can be spotwelded and emphasize again some of the more critical aspects of the welding of the aluminum alloys.

In spotwelding the assembly, the operator must exercise care to keep the electrodes clean at all times. The aluminum alloys are prone to surface alloy with the copper alloy electrodes. When this occurs the increased resistance that develops at the point of the electrode makes for irregular welds and prevents uniform current delivery. The operator should see to it that the edge distance and spacing is properly maintained and also that the spotweld pattern is symmetrical and uniform in size.

During the past few years the spotwelding of attaching plates or lugs to armor plate has been accomplished with considerable success. Because of the success in this field many spotweld technicians believe that with research and development many more alloy steels can be spotwelded in the future. This is a field which is now being actively explored and is the subject of research investigations at the Ryan Aeronautical Co.

Materials having resistance of equal value can be spotwelded together even though their chemical composition is not the same. It is preferable to weld materials of similar composition. In the aluminum alloys we find that the electrical resistance will vary

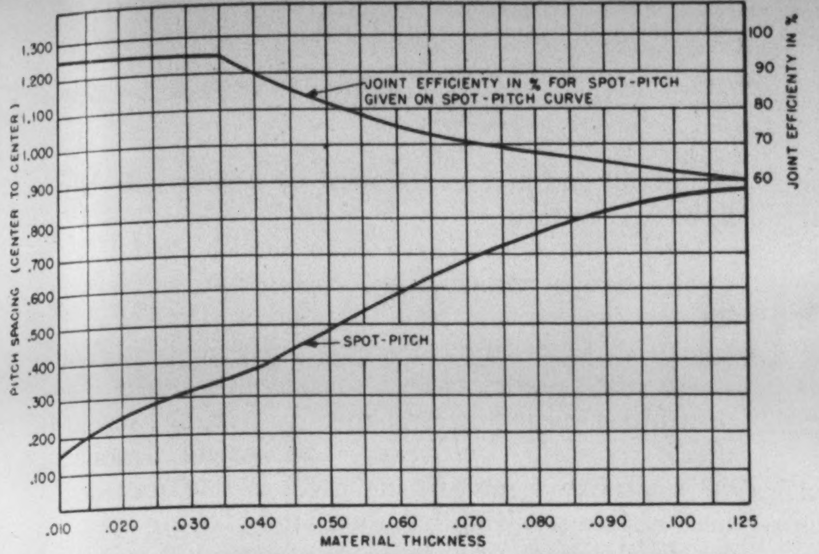


Chart III: Spotweld pitch and joint efficiency curves for single row pattern.

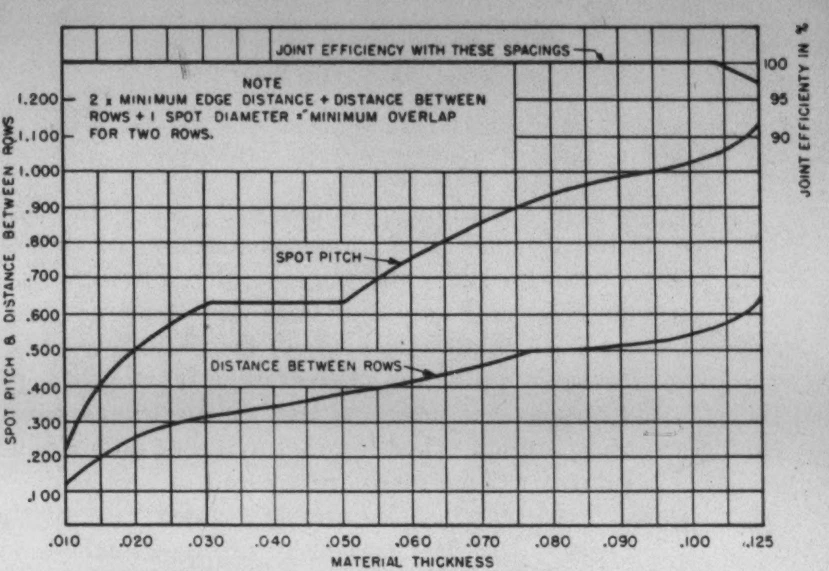


Chart IV: Spotweld pitch and distance between rows curves for two and three row patterns.

according to the chemical composition of a given alloy. The thinnest sheet is the determining factor in developing strengths of the spotweld. For this reason the designer must bear in mind that a wide variation in sheet thicknesses is not desirable because only a small proportion of the total strength of the thicker member can be utilized. Keeping the thicknesses of the gages to be spotwelded as similar as possible allows for uniform penetration, rapid production, and tends to prevent critical spotwelding conditions. A ration of 3½ to 1 thickness limits between two sheets should not be exceeded.

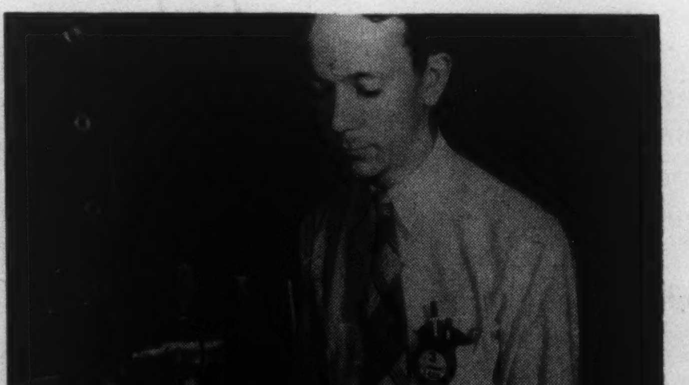
In the absence of a design manual the designers should consult the production man for the dimensions and clearances necessary to use the existing spotwelding equipment. This is sound practice because, while the gage combinations may be well within the capacity of the machine, sufficient head clearance must be allowed around the electrodes so that the holders and electrodes can enter the area to be spotwelded. The use of this type of information by the design engineer, together with spotweld diameter, edge distance, spot pattern and spacing, will yield two-fold results—sound design and increased production. Below are listed a few recommendations gathered from Ryan experience as to the type of information the designer should have at hand:

(1) Throat depth of spotwelder.
(2) Distance between arms.
(3) Diameter of electrode holders.
(4) Dimensions and shapes of standard electrodes commonly used by the production department.
(5) Angular set-ups possible on the machines available.
(6) Special electrodes, such as offset and others, which are available.
(7) Minimum and maximum clearances required by production for the fabrication of channels, hat sections, Z-bars and others.

While it is not the intent of this discussion to persuade the reader that spotwelding is an all-purpose method of manufacturing, there are, nevertheless, many cases in which spotwelding can replace rivets in lightly stressed assemblies. In some instances the substitution can be made direct, while in others a slight modification in the design of the part may be required. Where redesign is indicated, the increased production and decreased cost will most certainly offset the expense incurred.

Preparing for Spotwelding

Because of the high electrical conductivity and rapid heat transfer which is characteristic of aluminum alloys, extreme care must be taken in their preparation for spotwelding. Surface cleanliness is one of the primary requisites for consistency in the spotwelding of these alloys.



Ryan-designed electrodes are used for spotwelding this inaccessible aluminum vane. Bottom electrode is copper backed with steel for high strength.

The cleaning operation will vary, depending upon the material. The principal function of this cleaning operation is for the purpose of removing oils, greases and general contamination and freeing the surface of any contaminants whose electrical resistance would prevent a uniform current flow through the material. Considerable literature has been written regarding the most suitable cleaning methods, but only a brief word or two will be mentioned here.

Roughly, the cleaning is divided into two general types: (1) Mechanical brushing in which steel or wire brushes or, in some cases, rubber bonded abrasive wheels will lightly polish the surface of the material to be spotwelded in the weld area. The initial cost of this equipment is rather low, although the labor cost is quite expensive. Because of the difficulty of obtaining consistently uniform results, and because of the danger of removing the protective layer of aluminum from alclad, this method has not achieved general use. (2) Chemical solutions. A wide variety of chemical solutions are available, all of which essentially perform the following functions:

Step 1. Removal of oil and grease.
Step 2. Rinsing.
Step 3. Removal of oxide and establishing a uniform surface.
Step 4. Rinsing and drying.

Stainless steels (18:8 type) can be satisfactorily cleaned for spotwelding by one of two methods: annealing followed by a chemical pickle and rinsing, or, in the event the parts are oily and greasy, removal of the oils and greases followed by rinsing and then a light acid etching.

Steel parts which have been sand-blasted have a surface which renders them unsuited to spotwelding for two reasons: a certain amount of silica from the sand is entrapped or embedded in the metal surfaces. These silica particles offer considerable resistance to electrical current flow and this "by-passing" seriously affects spotweld consistency. The second reason for the unfitness of sand-blasted steel is that the roughened surface resulting from the sand-blasting prevents the development of a uniform electrical contact and current flow so that the spotweld formed varies in strength and is usually below minimum requirements.

Parts which have been sand-blasted can be prepared for spotwelding by annealing them at a scaling temperature followed by a regular stainless steel chemical pickle. In some cases of severe sand-blasting it may be necessary to scale and pickle the parts twice.

Following the cleaning and drying of the parts, the next general operation is assemblying. Because these assemblies are normally handled by the spotwelder and his helper, small assemblies are the rule and weight is usually limited. The assemblies are secured by either spot-tacking or mechanical Cleco fasteners or clamps.

Considerable difficulty can be caused for the spot welder if the assemblies are not handled in such a manner as to keep them clean. Chips lodged between sheets, oils, greases and general contamination which can mar the surface of these parts during assembly can cause trouble.

"Spot-tacking" exhaust manifold half-stampings together prior to their seam welding. Ryan has developed this method into a rapid technique.

MATERIALS & METHODS MANUAL

26

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Magnesium Alloys

by T. C. Du MOND,

Managing Editor, MATERIALS & METHODS

Magnesium alloys came into real prominence as engineering materials during the past few years. Although continued scarcities of some of the other basic metallic materials continue to suggest investigation of magnesium's use for a wide variety of products, the many favorable characteristics of this limitless material are finding new friends for it every day. Presented here is a discussion of the most frequently used magnesium alloys and suggestions as to the most satisfactory means of fabricating those alloys into finished products.

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Materials & Methods, May 1947

(Published since 1929 as Metals and Alloys)

Typical Characteristics of Magnesium Alloys

	Alloy No.			Nominal Composition (Mg = Remainder)			Heat Treatment†	Specific Gravity (75 F)	Weight, Lb./Cu. In.	Melting Point, F	Tension						Compression M Psi.		Shear M Psi.	Brinell	Rockwell E	Fatigue M Psi.	Impact Izod Ft./Lb.	Resistance to Salt Water, A = Best	Relative Cost A = Lowest	Color Code AS = Aluminum Stripe
											Ultimate Strength M Psi.		Yield Strength M Psi.		% Elong. in 2 In.											
	ASTM	DOW	AMC	Al	Zn	Mn					Typ.	Min.	Typ.	Min.	Typ.	Min.	Ult. Str.	Y'd. Str.								
Castings	A10	G	240	10.0	—	0.1	AC	1.81	0.066	1100	22	18	13	10	2	1	48	13	17	54	65	10	2	D	A	Purple
				10.0	—	0.1	HT	1.81	0.066	1100	33	29	12	10	8	5	50	12	19	52	62	12	4	D	B	Purple
				10.0	—	0.1	HTA	1.81	0.066	1100	34	29	19	17	2	—	54	19	21	69	80	10	2	D	C	Purple
	AZ63	H	265	6.0	3.0	0.2	AC	1.83	0.066	1135	29	24	14	10	6	4	45	14	18	50	59	11	3	C	A	Green
				6.0	3.0	0.2	ACS	1.83	0.066	1135	29	24	14	10	5	2	—	—	—	—	—	11	—	C	B	Green
				6.0	3.0	0.2	HT	1.83	0.066	1135	40	34	14	10	12	7	46	14	19	55	66	14	5	C	B	Green
				6.0	3.0	0.2	HTA	1.83	0.066	1135	40	34	19	16	5	3	50	19	20	73	83	13	2	C	C	Green
				6.0	3.0	0.2	HTS	1.83	0.066	1135	40	34	17	13	7	4	—	—	—	59	71	13	—	C	C	Green
	AZ92	C	260	9.0	2.0	0.1	AC	1.82	0.066	1110	24	20	14	10	2	1	55	16	18	65	77	11	1	C	A	Orange
				9.0	2.0	0.1	ACS	1.82	0.066	1110	24	20	14	11	2	—	—	—	—	—	—	11	—	C	B	Orange
				9.0	2.0	0.1	HT	1.82	0.066	1110	40	34	16	10	10	6	60	16	20	63	75	14	4	C	B	Orange
				9.0	2.0	0.1	HTA	1.82	0.066	1110	40	34	23	18	2	1	70	23	21	84	90	13	1	C	C	Orange
				9.0	2.0	0.1	HTS	1.82	0.066	1110	40	34	20	16	3	1	—	—	—	75	83	13	—	C	C	Orange
	M1	M	403	—	—	1.5	AC	1.76	0.064	1200	14	12	4.5	—	5	3	27	4.5	11	33	3	—	9	B	B	Yellow
	AZ90	R	263	9.0	0.7	0.2	—	1.81	0.063	1120	33	—	22	—	3	—	58	22	20	60	72	14	2	A	B	Blue
Bars	AZ31X	FS-1	C52S	3.0	1.0	0.3	—	1.77	0.064	1160	40	35	30	22	15	10	60	17	19	49	57	14	—	A	B	Red-AS
	AZ61X	J-1	C57S	6.5	1.0	0.2	—	1.80	0.065	1145	45	40	32	26	15	11	—	20	—	58	70	18	—	A	C	Gray-AS
	AZ80X	O-1	C58S	8.5	0.5	0.2	—	1.80	0.065	1130	49	43	33	25	11	9	—	22	—	55	77	19	—	A	D	White-AS
	M1	M	3S	—	—	1.5	—	1.76	0.064	1200	38	30	26	20	10	3	—	14	—	42	41	9	—	B	A	Yellow
Shapes	AZ31X	FS-1	C52S	3.0	1.0	0.3	—	1.77	0.064	1160	38	33	26	20	14	8	—	15	—	50	59	—	—	A	B	Red-AS
	AZ61X	J-1	C57S	6.5	1.0	0.2	—	1.80	0.065	1145	44	40	28	22	16	9	—	19	—	64	76	—	—	A	C	Gray-AS
	AZ80X	O-1	C58S	8.5	0.5	0.2	—	1.80	0.065	1130	46	41	29	25	9	6	—	22	—	67	78	—	—	A	D	White-AS
	M1	M	3S	—	—	1.5	—	1.76	0.064	1200	34	29	20	17	9	3	—	11	—	46	50	—	—	B	A	Yellow
Tubing	AZ31X	FS-1	C52S	3.0	1.0	0.3	—	1.77	0.064	1160	36	32	21	16	16	8	—	15	—	46	51	—	—	A	B	Red-AS
	AZ61X	J-1	C57S	6.5	1.0	0.2	—	1.80	0.065	1145	40	36	21	16	14	7	—	15	—	50	60	—	—	A	C	Gray-AS
	M1	M	3S	—	—	1.5	—	1.76	0.064	1200	33	28	21	—	9	3	—	10	—	42	41	—	—	B	A	Yellow
Forging	AT35	D	65S	3.5	*	0.5	—	1.87	0.067	——	40	36	28	22	12	7	—	21	16	52	—	10.5	—	C	B	Tan
	AZ61X	J-1	C57S	6.5	1.0	0.2	—	1.80	0.065	1145	43	38	26	22	12	6	—	17	21	55	66	16	—	A	B	Gray-AS
	AZ80X	O-1	C58S	8.5	0.5	0.2	—	1.80	0.065	1130	46	42	31	26	8	5	—	25	22	69	80	18	—	A	C	White-AS
		O-1a	C58S-O	8.5	0.5	0.2	a	1.80	0.065	1130	50	42	34	28	6	2	—	28	—	72	82	16	—	A	D	White-AS
		O-1	C58S	8.5	0.5	0.2	HTA	1.80	0.065	1130	50	42	34	28	5	2	—	27	—	72	82	16	—	A	E	White-AS
	M1	M	3S	—	—	1.5	—	1.76	0.064	1200	36	30	23	18	7	5	—	—	—	47	54	—	—	B	A	Yellow
Sheet	AZ31X	FS-1a	C52S-O	3.0	1.0	0.3	a	1.77	0.064	1160	37	32	22	—	21	12	—	16	21	56	67	12	—	B	B	Red-AS
		FS-1h	C52S-H	3.0	1.0	0.3	h	1.77	0.064	1160	43	38	33	26	11	4	—	26	23	73	83	14	—	B	B	Red-AS
	AZ51X	JS-1a	C54S-O	5.0	1.0	0.2	a	1.79	0.065	1150	40	—	23	—	18	—	—	15	20	59	71	14	—	A	D	Brown-AS
		JS-1h	C54S-H	5.0	1.0	0.2	h	1.79	0.065	1150	47	—	34	—	10	—	—	30	21	72	82	16.5	—	A	D	Brown-AS
	M1	Ma	3S-O	—	—	1.5	a	1.76	0.064	1200	33	28	15	—	17	12	—	12	17	48	55	9	—	C	A	Yellow
		Mh	3S-H	—	—	1.5	h	1.76	0.064	1200	37	32	29	22	8	4	—	20	17	56	67	10	—	C	A	Yellow

Modulus of Elasticity—6,500,000 psi.

Coefficient of Thermal Expansion—0.000016 per F (65 to 750 F)

Notes: * Tin 5.0%. † Heat treatment: AC = as cast, HT = solution heat-treated, HTA = heat-treated and aged, S (ACS and HTS) = stabilized, a = annealed, h = hard rolled.

Introduction

Although magnesium has been pro-uced and used for many years, it did ot earn important recognition as an ngineering material until the recent ar placed a premium on lightness ombined with strength. In order to educe the weight per horsepower of ircraft, plane manufacturers used mag-esium wherever possible, and, as a matter of fact, airplane producers were nd continue to be the largest con-umers of this material. Now, however, ll types of metal fabricators are at east considering magnesium, and many ave found it to meet all the require-ments of their products.

Magnesium is now being produced t the rate of about 1,800,000 lb. per month, and by the end of 1947 the ate is expected to exceed 50,000,000 lb. a year. This compares with a yearly utput of 6,000,000 lb. a year prior to he war.

In addition to its physical character-istics, which compare favorably with most other structural materials and ex-ceed all other present day available materials as to lightness, magnesium has the advantage of having a source of supply that will not be exhausted as ong as there remains sea water from which to extract the mineral. One ubic mile of sea water contains about 10,000,000 lb. of magnesium, and the methods of extraction have now been perfected to the state where magnesium an be produced and marketed for 20½c per lb. There is a strong likeli-hood that this price will be lowered before too long. Although magnesium now costs about twice as much as ordinary steels on a per pound basis, t is cheaper than steel when con-idered from the volume standpoint, ince its weight is about one-fourth hat of steel.

Magnesium can be fabricated by lmost any of today's universally used processes, including stamping, draw-ing, machining, forging, welding, spinning, extruding. It can be cast by the sand, permanent mold and die casting methods. It can be plated, painted or anodized. In some of these processes a little more care must be exercised than when working other commonly used structural metals, but in no case is it really difficult to work. It has earned the reputation of being the easiest metal to machine, lending itself to heavy cuts at high speeds and providing fine finishes at such speeds.

There has been some resistance to magnesium on the part of some possible users, due to the impression that magnesium is highly flammable in all its forms. This belief has been fostered in part by the knowledge that powdered magnesium was used in incendiary bombs. Further fuel is added to the fire by the fact that magnesium is flammable in a *finely divided* state, due to the rapidity of oxidation. However, it has been proved through all types of laboratory and action tests that solid magnesium products do not burn and that if proper precautions are observed even magnesium chips and powders can be handled safely. Partially to prove to the public that magnesium will not burn, and partially to add another outlet for the material, several manufacturers have produced magnesium griddles. Reports indicate that while magnesium is not superior in this application it is satisfactory and that it definitely does not burn.

In its pure state, magnesium is of no value as a structural material, since by itself it does not have sufficient mechanical strength to carry more than moderate stresses. Fortunately, magnesium alloys readily with small amounts of most other elements, with the exception of iron and chromium. It will absorb small amounts of manganese. However, only those alloys containing aluminum or zinc or both have suitable strength and forming characteristics. Generally the alloying elements are limited to about 10%.

Although extreme lightness and excellent machinability are the most frequently mentioned characteristics of magnesium alloys, there are many other characteristics which make such alloys desirable structural materials. These include:

Strength

Most magnesium alloys have excellent strength-weight ratios and thus can be used in many highly stressed structures. In castings, tensile strengths of 35,000 to 40,000 psi. are reached, and in the wrought condition tensile strengths of from 45,000 to 53,000 psi. are achieved. Tensile and yield strengths decrease at elevated temperatures, so magnesium alloys are generally not recommended for use at temperatures exceeding 400 F. However, the strength properties of magnesium are changed negligibly at *sub*normal temperatures. The modulus of elasticity of magnesium alloys is 6,500,000 psi., a value much lower than that of other structural metals. Because of this modulus of elasticity, magnesium alloys have a superior capacity for elastic shock absorption.

Corrosion Resistance

In the early history of magnesium alloying and fabrication, this material earned — often unjustifiably — a poor rating as far as corrosion resistance was concerned. Since those days, as a result of comprehensive test programs, improvements in alloying and higher purity in the alloys, they are now accepted as on a par with other materials. Magnesium alloys do not corrode in dry air; in ordinary outdoor exposure magnesium will corrode less than a block of steel, since the original coating formed protects against further corrosion.

Magnesium and magnesium alloys corrode rapidly when completely immersed in salt water or when wet for substantial periods with salt solutions. The most serious corrosion problem exists when magnesium is in contact with other metals in the presence of moisture, due to galvanic corrosion.

The alloys are attacked by all acids with the exception of strong hydrofluoric acid and chromic acid, and so are not recommended for use where they will come into contact with any acids except those mentioned. Magnesium is highly resistant to solutions of alkalies, borates, fluorides and chromates.

Thermal and Electrical Properties

The coefficient of thermal expansion of magnesium alloys is approximately twice that of ferrous alloys, but this difference has little or no practical importance in assembled structures. Thermal conductivity is lower than that of aluminum alloys but greater than that of ferrous alloys.

On a volume basis, pure magnesium has an electrical conductivity approximately 38% that of copper and 60% that of pure aluminum.

Alloys in Magnesium

In its pure state, magnesium is of no value as a structural material, since by itself it does not have the mechanical strength necessary when more than moderate stresses are involved. Fortunately, magnesium is readily alloyed with small amounts of most other elements with the exception of iron and chromium. It does not readily alloy with manganese, but will combine with small amounts. However, only those alloys containing aluminum, zinc or manganese, or combinations of any or all of these elements, have suitable strength and forming characteristics.

Aluminum is the most commonly used alloying element in magnesium alloys. Used in amounts varying from 3 to 10%, aluminum results in refined grain structure, increased strength and hardness, and decreased ductility. The latter is true when aluminum passes 5%. With 13% aluminum, magnesium alloys are too brittle for structural purposes. When 30% aluminum is involved, the alloy resembles glass in many characteristics.

Zinc, usually in amounts of 1 to 3%, are added to magnesium alloys primarily to aid corrosion resistance of magnesium alloys, although it has some beneficial effect on physical characteristics.

Manganese, limited to 0.3% max., also helps provide better corrosion resistance. Manganese retention decreases in magnesium alloys as the aluminum content rises. Thus, while 0.35% manganese is absorbed when aluminum is at 4%, this retention is reduced to about 0.10% when aluminum is increased to 12%.

Alloys have been developed using tin, silver, copper, zirconium and cerium as alloying elements, although they are not too generally accepted yet. The tin alloy, AT 35, is used for forging. Cerium-bearing alloys have good properties at elevated temperatures. Zirconium alloys are under investigation for high-strength uses.

Experiments involving beryllium indicate that use of about 0.005% of this element make the alloys less susceptible to burning.

Certain of the magnesium alloys are improved by heat treatment. This is true of those casting alloys containing 6% or more of aluminum. With more than 8% aluminum a solution heat treatment followed by a precipitation or aging treatment develops a greater hardness and higher yield strength in the alloy. With less than 6% aluminum in the alloys, heat treatment and aging have little or no significant effect.

In casting alloys, proper alloying and heat treatment makes possible the tripling of tensile strength, doubling elongation, an increase in yield strength up to seven times, tripling hardness and doubling of the endurance limit.

With wrought alloys, proper alloying and heat treatment results in comparable improvement, such as doubling of tensile strength, tripling elongation, tripling yield strength, doubling hardness and increasing endurance limit 3½ times.

Major producers of magnesium alloys have their own private designations for the commercial alloys, but most producers also list the ASTM designations. Such designations are based upon the nominal alloying elements. For example, in the designation A10, the alloy contains 10% aluminum. In AZ92, aluminum is 9% and zinc 2%. M1 is a manganese alloy in which the manganese averages 1%. The newer cerium alloys are designated by the prefix letter E.

Practically all other elements in magnesium alloys are there as impurities. Recently there have been developed alloys in which these elements, particularly nickel and iron, are limited to a very low point. Such controlled purity alloys are indicated by the letter X after the ASTM designation.

There are now approximately 8 to 10 ASTM designated basic alloys, but the variations of these raise the total number of alloys to at least twice that number.

Available Forms

Commercial magnesium alloys are available in practically all accepted structural forms, including: sand permanent mold and die castings, forgings, extruded shapes, and in sheets, plate and strip.

Castings, Sand

Magnesium sand castings range in size from a very few ounces to several hundred pounds in weight and in a wide variety of shapes. Special equipment and some different casting techniques are required, particularly in molding and pouring. Sand castings show tensile strengths ranging from 14,000 to 40,000 psi. and yield strengths from 4,500 to 22,000 psi., depending on the alloy and heat treatment.

Two alloys, AZ92 and AZ63, are the most commonly used for castings. Both have high strength and good casting characteristics. AZ92 is the better of the two where pressure tightness is required, and AZ63 where strength is most desired.

Alloy M1 is often used for casting even though it has inferior casting characteristics. M1 has excellent weldability; thus, it is often specified in castings which must later be welded.

Both AZ92 and AZ63 are subject to growth, but after heat treating growth is negligible.

Castings made of AZ92 and AZ63 can be furnished in any one of a number of heat treated conditions, depending upon the properties required. Alloy M1 is not heat-treatable.

Solution heat treatment puts alloying elements into solid solution and results in high tensile strength and maximum ductility. In the *heat-treated and aged* condition, alloying ingredients are precipitated, providing maximum yield strength and hardness.

Stabilization in the *as cast condition* provides higher creep strength and less growth at elevated temperatures. When *heat treated* and *stabilized,* the castings show higher creep strength and less growth at elevated temperatures. This treatment also results in some aging with a corresponding increase in yield strength over that of the heat treated condition.

Magnesium alloy sand castings find a wide range of applications, including those aircraft parts which must be light in weight and have high strength and high shock resistance. Portable tools and items of a like nature are also ideal products for these castings.

Castings, Permanent Mold

Magnesium alloys are suited to casting by the permanent mold and semipermanent mold methods. The mechanical properties of such castings are lmost identical with sand castings. This method is used when quantities re sufficient (500 to 1,000 pieces) to ustify cost of equipment. Semi-permanent molding is used on lesser quantities or where coring is too complicated for the full permanent mold method.

Advantages in molding by this method include, of course, faster production, plus close control on sizes and dimensional tolerances and better surfaces. Secondary advantages are reduced weight and a reduction in the amount of machining required.

Alloys A10, AZ92 and AZ63 are all supplied as permanent mold castings. AZ92 is the most widely used because it combines good casting characteristics, with good mechanical properties and high corrosion resistance. A10 has superior casting characteristics, but it is not so high in mechanical properties and corrosion resistance as is AZ92. Alloy AZ63 is not a frequently used alloy, since it is harder to handle in the foundry, but it is used on some special applications.

Permanent mold casting alloys are susceptible to the same types of heat treatment as the sand casting alloys, and properties improve in about the same degree.

During the late war permanent mold castings were used for aircraft engine starters and generator housings. The textile industry is now using large quantities of this type of casting for warp and section beams.

Castings, Die

For the vast majority of magnesium alloy die castings only one alloy—AZ90—is used. Other alloys are used in special circumstances, but only upon specific recommendations of the alloy suppliers. Magnesium alloy die castings show yield strength of about 22,000 psi. and ultimate strength of 28,000 psi. AZ90 has a highly desirable combination of physical and casting properties and produces castings with extremely smooth surfaces and high dimensional accuracy, thus requiring a minimum of machining. There is little tendency for AZ90 to grow or distort. It is furnished only in the "as cast" condition.

As with other metals, die casting of magnesium alloys becomes economical when quantities needed exceed 1,000 pieces. However, on some parts die casting is practical for as few as 500 pieces. Die cast parts can be even lighter than magnesium products of other methods since thinner walls are possible.

At present, magnesium alloy die castings are limited by the size of die casting equipment available. Where excessive wear or bearing stresses are anticipated, steel, bronze or brass inserts are recommended in magnesium die castings. These can be cast-in without difficulty.

Forgings

When parts of magnesium alloy are to be subjected to high or repeated stresses and impact they are often used as forgings. As with other metals, forging results in a fine grained, sound structure. Since most magnesium alloys must be forged at relatively slow speeds, hydraulic presses are most frequently used, although some mechanical presses are suitable. At least one of the alloys—M1—can be forged by any means. Generally, magnesium alloys are forged from extruded rods.

The strongest forging alloy is AZ80X. This alloy has good physical properties, good corrosion resistance, and can be aged to obtain additional yield strength.

Alloys AT35 and AZ61X provide moderately high mechanical properties. Both can be forged in either type of presses, while AZ61X can be also forged by hammers. AT35 is often chosen because it is a low cost alloy which has relatively good properties. AZ31X likewise can be forged in all types of equipment.

When forgeability and weldability are desired in the same part, alloy M1 is often chosen. This alloy can be forged by hammer or press equipment.

Good strength, light weight and pressure tightness of magnesium alloy forgings make them suitable for many applications. Some typical applications

Compositions and Uses of Most Common Magnesium Alloys

ASTM Des.	Al	Mn	Zn	Mg	Uses
AZ92	9.0	0.1	2.0	Rem	Sand and permanent mold castings, heat treatable
AZ31X	3.0	0.3	1.0	Rem	Extrusions, plate, sheet and strip
A10	10.0	0.1	—	Rem	Permanent mold castings, heat treatable
AZ63	6.0	0.2	3.0	Rem	Sand castings, heat treatable
AZ61X	6.5	0.2	1.0	Rem	Extrusions, forgings and sheet
M1	—	1.5	—	Rem	Extrusions, forgings, plate, sheet strip. Also used for special sand castings
AZ80X	8.5	0.2	0.5	Rem	Extrusions and forgings, heat treatable
AZ90	9.0	0.2	0.6	Rem	Die castings
AZ51X	5.0	0.15	1.0	Rem	Rolled sheet, strip and plate
AT35	3.5	0.2	0.3	Rem	Forgings

Heat Treatments for Magnesium Alloy Sand Castings

Type	Designation	Temp. Range—Deg. F	Purpose
Solution Heat Treated	HT	500 to 800	To put alloying ingredients into solid solution. Results in high tensile strength and maximum ductility.
Heat Treated and Aged	HTA	300 to 500	To precipitate alloying ingredients. Provides maximum yield strength and hardness.
As Cast and Stabilized	ACS	425 to 550	To provide higher creep strength and less growth at elevated temperatures.
Heat Treated and Stabilized	HTS	425 to 550	To provide higher creep strength and less growth at elevated temperatures. Results in some aging or precipitation with resultant increase in yield strength over that of the heat treated condition.

are aircraft engine bearing caps, bearing housings, hinges, valve and pump bodies, levers, brackets, rocker arm supports, and many others.

Extrusions

Magnesium alloys are well suited to extruding and thus can be produced in a wide variety of plain and intricate shapes. Many magnesium alloy extrusions combine two or more standard structural shapes. Extrusions are relatively inexpensive since the operation is low cost, as are the necessary dies.

Standard shapes include round rod and bar sizes—square, rectangular and hexagonal.

Extruded alloys range from high-strength alloy AZ80X down through AZ31X and AZ61X to M1. The AZ31X and AZ80X alloys have intermediate strength properties, while M1 has only moderate strength but has high corrosion resistance and good weldability.

The maximum width of extrusions is approximately 12 in. with thicknesses of from 0.035 in. up and in lengths from 5 ft. up, depending upon the size and shape of the extrusion. Standard maximum lengths are 22 ft.

Extruded magnesium shapes are used as forging stock, to make magnesium furniture, and as structural members in aircraft, and truck and trailer parts.

With the exception of AZ80X, all of the above listed alloys are available in extruded tubing. Tubing is being supplied with outside diameters ranging from 3/16 in. to 12 in. and with wall thicknesses of from 0.022 in. to 1 in.

Since magnesium alloys are extremely well suited to machining, much of the output of round and square extrusions is consumed in producing screw machine parts. For this use, AZ61X and AZ31X are the preferred alloys.

Rolled Sheet, Plate and Strip

Three of the standard magnesium alloys are available in sheet and plate form, and two of these are also obtainable in coiled or straight strip. All have a relatively high resistance to corrosion.

Magnesium sheet can be arc, gas and spot welded; formed, drawn, spun and riveted. Sheet and plate are being used for aircraft wings, canoes, bus and trailer bodies, fuel tanks and many other assemblies where this wrought form is applicable and where light weight is desired. Magnesium sheet and plate provides ultimate strengths from 33,000 to 43,000 psi., yield strengths of from 15,000 to 34,000 psi., and Brinell hardnesses between 48 and 73.

Alloy M1 is the most widely used alloy in the form of sheet, plate or strip. It is used where moderate stresses are involved and where good weldability and formability is required. Welding can be by either the gas or the helium arc method.

AZ31X has better strength and formability than M1 but cannot be welded so successfully. When welds are unrestrained and allowances can be made for shrinkage, this alloy is satisfactory. AZ31X is available in sheet, plate and strip.

Highest strength is available in AZ61X, but at a sacrifice in formability. It is welded readily through the helium arc method. This alloy is not ordinarily supplied as strip.

All three of these alloys are furnished in the annealed, as rolled and hard conditions. Where forming is to be done, or where flatness is important, the annealed condition is usually specified.

Sheet magnesium alloy comes in thickness ranging from 0.016 in. to 0.219 in. and in widths from 24 in. to 48 in. The wider pieces are only available in the thicker sheet. Plate ranges in thickness from 0.250 in. to 1.0 in. in the same widths as sheet. Strip is available in widths up to 8 in. All come in lengths up to 21 ft.

Joining Magnesium Alloys

Most of the common joining methods can be used on magnesium alloys, but with varying degrees of success. Methods applicable include riveting, gas welding, inert gas shielded arc welding, resistance welding, glueing and soldering. Each of these methods will be discussed under this section.

Riveting

Riveting is the most commonly used method of joining magnesium alloys and it is a comparatively simple operation, although certain precautions must be observed.

Aluminum alloy rivets are most frequently used, since magnesium alloy rivets would work-harden too much if driven cold. Although aluminum alloys 2S, 3S, 53S, A17S-T and 56S all are used, the latter is generally preferred. When riveting dimpled sheet, 56S-O is used with 56S-¼ H chosen for other applications. The aluminum alloy rivets are anodized to overcome any tendency toward corrosion. If salt atmospheres are anticipated, rivets should be given a coat of zinc chromate.

Under certain circumstances, steel screws and rivets can be used. When such is the case, these materials are zinc or cadmium plated, and as an added protection against galvanic corrosion, a zinc chromate or barium chromate paste is used to break the seal between steel and magnesium.

Rivet holes in magnesium alloys are generally provided by drilling, since punching creates several problems, including that of work-hardening and thus fostering cracking in the holes. If it should be found necessary or desirable to punch rivet holes, punching should be done when the alloy is heated to above 400 F. Holes thus formed should be reamed to prevent cracking.

If parts to be riveted are drilled together, it is always important to clean out the holes so that all chips are removed from the contacting surfaces. When parts of a structure are to be drilled separately, it is good practice to drill holes slightly undersize and ream in final assembly. Clearance should be kept to a minimum between rivet and hole.

Squeeze riveters are preferred when riveting magnesium alloys, although pneumatic hammers can be used. Squeeze riveters provide accurate control of driving pressures, give better centered formed heads, result in consistent rivet strength, and minimize damage to the sheet by overdriving.

Practically all of the commonly furnished heads on aluminum alloy rivets are usable, as are the most frequently used driven heads. In light work, flat bucktail driven heads are most satisfactory.

Rivets, generally, are used in diameters approximately 3 times the thickness of the thickest sheet being joined. It is usually found better to use many small rivets than a few large ones.

In making riveted joints, recommended practice calls for the rivet holed to be placed from the edge a distance equal to 2½ times the rivet diameter. Three times the rivet diameter is used to determine minimum spacing between rivets.

Where flush riveting is desired, dimpling is usually used on sheet thinner than 0.050-in. Dimpling is done either with electrically heated dies or by preheating sheet and dies. Holes are punched about 15% undersize before dimpling and then drilled or reamed to proper size. On sheet over 0.040 in., machine countersinking is used.

When dissimilar metals are joined by riveting, it is necessary to place insulating gaskets of rubber, plastic or other non-conducting materials in the joint to prevent galvanic corrosion.

Gas Welding

Magnesium alloys of certain types are readily gas welded by means of oxyacetylene, oxyhydrogen or oxycarbohydrogen gas. The latter is preferred since its flame is easier to control and adjust and because it provides a cooler flame than oxyacetylene. Whatever the type of gas, a neutral flame is preferred since it helps prevent excessive oxidation.

The most suitable alloy for gas welding is M1 in sheets or as extrusions or sand castings. Gas welding of other wrought alloys is less satisfactory, although AZ31X, AZ61X, and AZ51X are weldable in short seams. AZ80X has even less weldability. This type of welding generally is not recommended for other magnesium alloys or for sand castings except those of alloy M1.

Gas welding is not recommended for any type of joint except plain butt joints, since the flux which must be used is likely to be entrapped in other types of joints and cause corrosion.

Weld strengths on sheet thicker than 0.05 in. varies from 60 to 90% of the strength of the parent metal, depending upon the alloy and its temper. In all gas welds, filler rod composition should be the same as that of the alloy being joined.

Special fluxes are used in gas welding magnesium alloys. These fluxes combine the proper melting range with the capacity of protecting the molten metal from oxidation and an ability to dissolve or absorb oxides or other reaction products of welding. The flux is furnished as a powder. Before using it is made into a paste by mixing two parts of flux with one of water.

Magnesium alloys are not satisfactorily welded to other metals, nor can they be cut by torch methods.

Briefly, here are the steps required to gas weld magnesium alloys:

1. Clean and brighten edges of seam (bevel or notch edges of heavy sections).
2. Preheat work where head is to be started. Preheat welding rod.
3. Apply flux to weld area and welding rod.
4. Tack weld the seam.
5. Weld about 2 in. at each end of seam.
6. Straighten out buckles, if any.
7. Cover tacks with flux.
8. Weld seam.
9. Straighten any buckles.
10. Remove remaining flux by cleaning.

In cleaning to joint areas, of course, all oils and dirts should be removed by standard cleaning methods. Edges and areas immediately adjacent to the weld are then brightened by wire brushing, filing or similar methods and then rubbed with a clean, dry cloth.

Seams are tack welded at intervals of ½ in. or more and then 1- to 2-in. welds are made at each end of the seam to minimize warping. Now the seam itself is formed and, if possible, completed in one pass. The material is preheated at the point where the seam begins. Should welding be halted and then resumed, the end of weld deposit is fluxed and again heated and welding carried on from this point. Flux is applied to both the weld area and the rod, and after tacking, these points are fluxed.

If oxidizing or burning should start at any point on the seam, welding should stop and the oxidized area removed before welding is resumed.

It is extremely important that welding flux be completely removed after welding to prevent corrosion in the weld, especially if porous areas are present, and they usually are. Cleaning must be done as soon as the metal is cool enough to handle. The joint is scrubbed in hot running water until all flux is loosened and washed off. Chromium-pickle or citric acid treatment is then recommended.

Finally, it is advisable to give a dichromate boil treatment. This step inhibits any small particles of flux which have not been completely removed. If the weld bead is ground down, the cleaning process should be repeated, since flux inclusions might be exposed in the grinding process.

Buckling can occur in any thickness of sheet or plate. Minor degrees of warping can be straightened by hammering with leather or wood mallets, but large deformations should be hammered out only after heating the part to between 600 and 750 F.

Arc Welding

With the advent of inert-gas-shielded arc welding, this method of joining magnesium alloys is well on its way to becoming the most popular fusion welding process. Among its other advantages is the fact that there is less likelihood of warping and cracking. Popularly known as "Heliarc," this welding method can be used on all magnesium alloy sand and permanent mold castings, extrusions, forgings and sheet and plate. Since no flux is required when helium-arc welding is employed, there is no restriction on the type of joint employed, as exists with gas welding. Cleaning after welding is merely a matter of brushing off the surface of the weld bead.

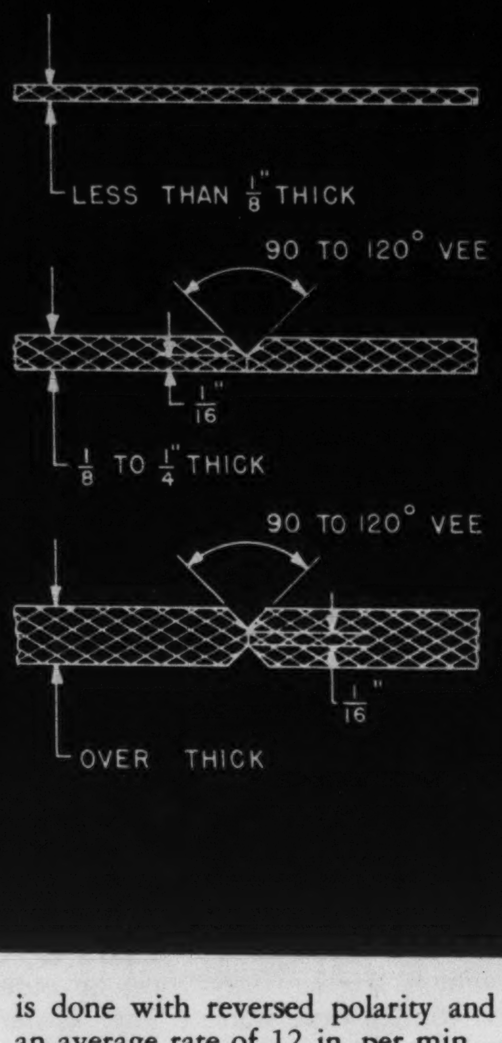
Although either argon or helium gas can be used, helium is now most common. Helium used must be pure and contain little water if any. Water in the gas decomposes during welding to produce hydrogen—resulting in high porosity—and oxygen, which forms an oxide film causing poor fusion and inclusions.

As with gas welding, helium arc welding requires the filler rod to be of the same composition as the alloy being joined. One exception is when welding AZ31X. In this case AZ61X rod, which produces a stronger weld metal, is used to reduce cracking. The electrode is of tungsten and is used in sizes from 3/32 to ½ in. in dia.

Direct current or rectified alternating current welding generators are used to provide 30 to 60 amp. at an arc potential of 18 v. or less. Fine control of welding current is a must. Welding

Recommended Stress Relieving Treatments for Arc Welded Magnesium Sheet

Alloy	Time at Temperature	Temperature—F ± 10 Deg.
AZ31X (Annealed)	15 min.	500
AZ31X (Hard Rolled)	1 hr.	265
M1 (Annealed)	15 min.	500
M1 (Hard Rolled)	1 hr.	400
AZ61X (Annealed)	15 min.	500
AZ61X (Hard Rolled)	1 hr.	400



Arc welding is most satisfactory when properly prepared joints are made.

is done with reversed polarity and at an average rate of 12 in. per min.

As in welding any metal, the magnesium alloy must be thoroughly cleaned. First a solvent is used to remove grease, oil and other processing dirt. Finally, aluminum oxide abrasive cloth or steel wool is used to remove chemical finishes, oxides and solvent films. The filler rod is also cleaned with steel wool to remove any oxide films which may have formed.

Material thicker than 0.125 in. should be beveled for butt welding, leaving a 1/16-in. root face. Thickness over 0.125 in. can be prepared with double V-grooves.

When welding, the torch and rod are moved along at a constant speed, and care is taken to see that the rod is melted in small drops and that it is not pushed into the molten puddle. It is important that the torch be held as close to the work as possible. Welding is done most satisfactorily when the bead is laid from one edge to the other without stopping. If welding is halted before finishing the pass, it should be resumed about ½ in. back of the point where the previous welding stopped. Many welders find it advisable to permit the helium to flow for several seconds after the arc is extinguished to prevent undue oxidation of the tungsten electrode.

Other steps taken to reduce warpage include the use of jigs whenever possible. The same jigs can be used in stress relief heat treatment following welding. When material is over ⅛-in. thick, multiple beads of weld metal should be laid, rather than attempting to fill the joint at one pass. Where warpage is serious, alternate tack welds or interrupted welding is recommended.

Cracking is minimized in welding certain alloys through the use of starting and stopping plates. Such plates are scrap pieces of stock butted against opposite ends of the joint. Welding starts in one plate and stops in the other. If a V-joint is being welded, the starting and stopping plates should be similarly beveled. In some instances it has been found advantageous to start welding at the center and weld out to the plates.

Preheating to between 200 and 400 F, where possible, has been found to minimize cracking, as does increasing the welding speed when cracking is encountered.

Grooved plates are sometimes desirable to back up the weld and prevent excessive metal "drop down." The backing can also be used after welding for straightening and in stress relieving.

Residual stress in the magnesium alloys should be relieved through heat treatment after welding. Depending upon the alloy, temperatures used range from 265 to 500 F and heating times vary from 15 min. to 1 hr. As indicated previously, heat treatment should be done with the weldment in jigs to prevent warpage. After heating the material should be cooled in still air.

Cleaning of helium-arc welded magnesium parts is a rather simple matter since no flux is required in this type of welding. The welds need only be wire brushed and they are ready for a chemical prepainting treatment. Excess weld bead can be removed by grinding, filing, routing and similar operations.

Resistance Welding

Practically all of the magnesium alloys can be joined by resistance welding. Depending upon the shape of part and the strength required, spot, seam, butt or flash welding can be employed. However, spot welding is the most commonly used. Different magnesium alloys can be welded to each other, but not to other metals.

As long as extremely close control over time, pressure and current is available, either standard a.c. equipment or any of the stored energy type welders is satisfactory. A.c. machines often cost less, but generally, the load demand of the stored energy welders is less. One company reports that a.c. machines require up to 450 kva., while stored energy units take up to 75 kva.

Resistance welding of magnesium alloys usually requires less current density than equally thick parts of aluminum alloy, because of the lower electrical conductivity of magnesium. Water-cooled hard copper alloy electrodes are used with magnesium, and usually are designed with dome tips. One reason for the water-cooled electrodes is to help reduce pick-up of magnesium on the electrodes. On some alloys, such as AZ61X sheet, as many as 100 to 150 welds can be made between cleaning electrode tips, while on such alloys as M1 the electrodes must be cleaned after every 10 to 20 welds.

It is extremely important that magnesium surfaces be well cleaned before spot welding. Solvent cleaning to remove grease, oils and dirt should be followed by mechanical cleaning of contacting surfaces and points of contact between the magnesium and the electrodes. A bright metallic luster, such as is needed, can be obtained by means of brushing with a fine stainless steel wire brush, stainless steel wool or fine aluminum oxide abrasive cloth. The abrasive cloth cleaning is essential if the sheet to be spot welded has been chemically treated.

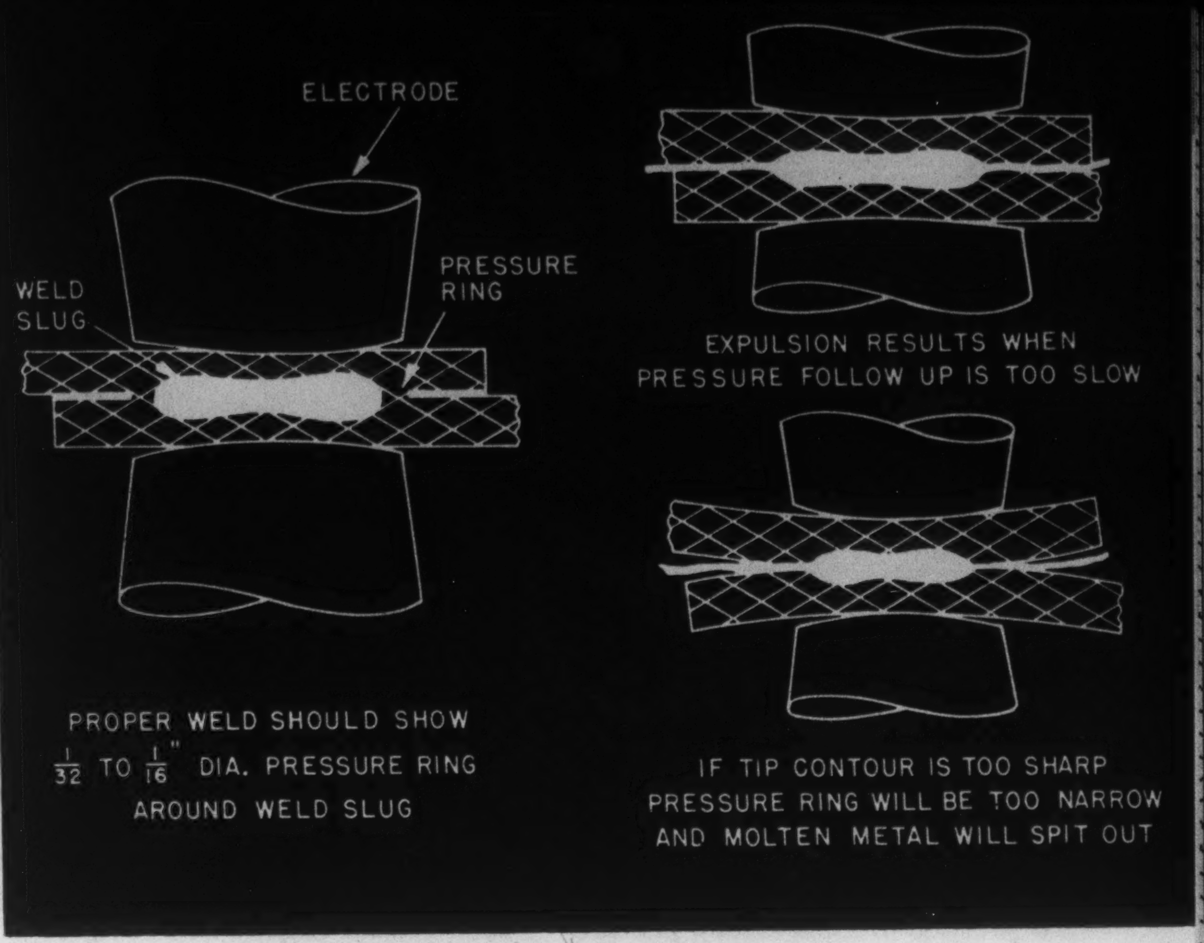
Although recommended current settings are available for all types of welding equipment, these are only approximate, and it is advisable to make trial welds to determine most satisfactory settings. Usually trial welds are made with lower current or lower voltage than suggested and then the values increased until the desired weld diameter or strength is obtained.

Sometimes expulsion of metal occurs between the parts being welded. Means of stopping such expulsion include: increasing welding pressure, decreasing welding current, increasing both the pressure and current, or by increasing electrode radius as well as increasing pressure and current. Expulsion sometimes results from improper or insufficient cleaning. Some of these same measures should be tried if there is excessive pick-up on the electrode.

Large differences in thickness should be avoided in alloys to be welded. In general, the thicker sheet should be no more than twice the thickness of the thinner. When there are great differences in thickness, an electrode with larger contact area should be used against the thicker material. If this precaution is not taken, the weld may have no penetration or insufficient penetration in the thinner sheet.

The same remedy used to correct expulsion and pick-up can be applied to overcome radial cracks in the weld. However, when taking these steps, caution must be observed to see that a lowering of shear strength in the weld does not result.

Since there is a possibility of copper from the electrode adhering to the magnesium alloy surface due to pickup, all joints should be cleaned after welding. Copper will accelerate corrosion. Cleaning should be done with aluminum oxide abrasive cloth or with buffing wheels impregnated with aluminum oxide polishing compounds. Cleaning should be followed by a suitable chemical surface treatment.


ELECTRODE
WELD SLUG
PRESSURE RING
PROPER WELD SHOULD SHOW $\frac{1}{32}$ TO $\frac{1}{16}''$ DIA. PRESSURE RING AROUND WELD SLUG
EXPULSION RESULTS WHEN PRESSURE FOLLOW UP IS TOO SLOW
IF TIP CONTOUR IS TOO SHARP PRESSURE RING WILL BE TOO NARROW AND MOLTEN METAL WILL SPIT OUT

Correctly and incorrectly made spot welds.

Other Joining Methods

Soldering—Some soldering is done on magnesium alloys, but not where stresses are involved. Soldering is not recommended for joining magnesium alloys or for joining magnesium to other metals. The chief use of soldering is in filling surface imperfections.

Two compositions are generally available for soldering. One, rather easy to apply, is composed of 60 cadmium, 30 zinc and 10% tin and melts at 315 F. Harder to apply is a composition containing 90 cadmium and 10% zinc, which melts at 500 F. The latter is used where heat must be applied after soldering, as in baking for drying finishes.

No flux is required in soldering magnesium alloys, but the surfaces to be soldered must be mechanically cleaned to a bright metallic luster through wire brushing, filing or sanding.

Brazing—With special fluxes and high strength filler rod materials, one magnesium alloy — M1 — has been brazed successfully. Investigation is continuing to perfect more universal brazing techniques.

Adhesive Bonding—In some cases bonding cements are being used to join magnesium alloys to other materials as well as to magnesium. Strength of bonded joints ranges from 1,000 to 4,000 psi. Corrosion resistance of such joints is said to be high.

Heat-pressure methods are used with the thermoplastic or synthetic rubber bases. Other bonding materials require heat only. Heat-pressure methods require pressures from 300 to 400 psi. and curing times of about 20 min. at temperatures of approximately 350 F.

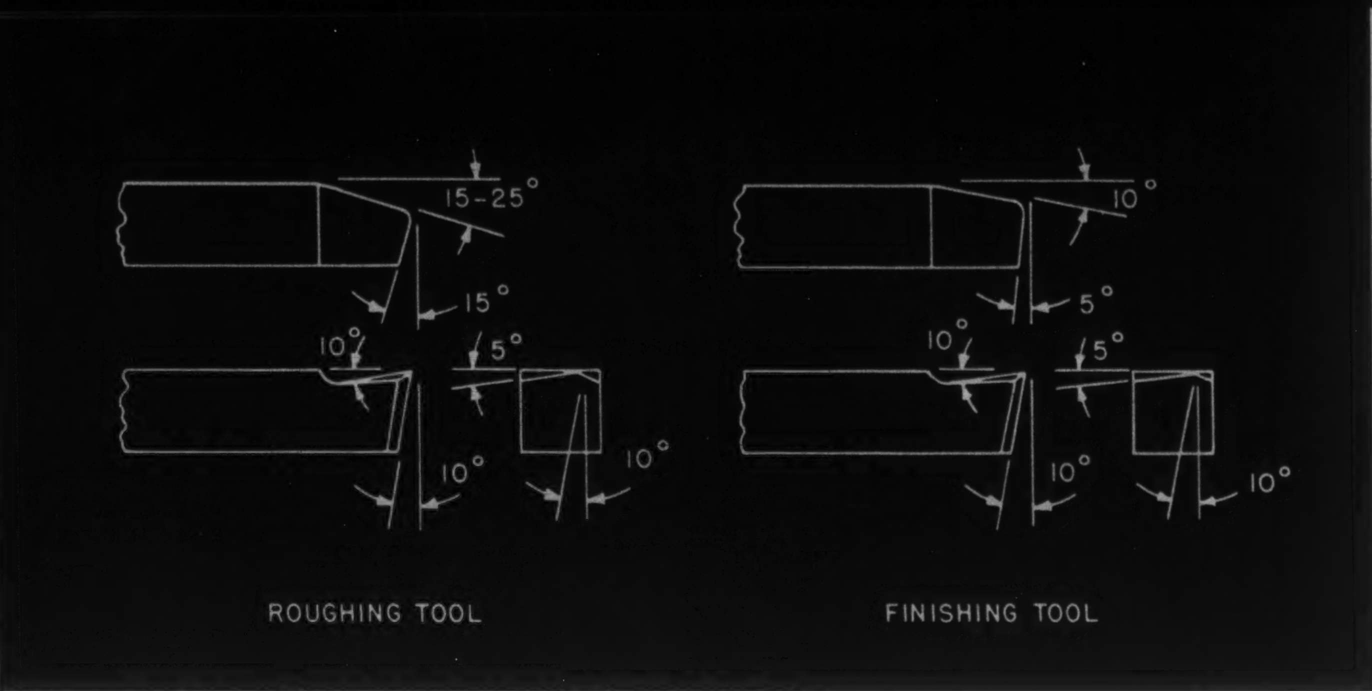
As yet adhesive bonding of magnesium alloys is not greatly used, but it is expected that this joining method will find general use when it is desired to join magnesium to nonmetallics.

Machining

Not the least of the charms of magnesium is its ease of machining. Magnesium is the best machining of the commonly used engineering materials, and such machining requires less power per volume of metal removed than any of those materials. Likewise, depths of cut and rates of feed are higher with magnesium alloys.

Since there is little tendency for the metal to tear or drag, excellent surface finish results, often making grinding unnecessary, when coupled with the fact that dimensional tolerances of a few thousandths of an in. can be attained with standard machine tools. Tool life in machining magnesium alloys is exceptionally good, especially when carbide or carbide-tipped tools are used. Generally, magnesium alloys are machined without coolants, except to reduce the fire hazards.

The rate of heat conductivity and low modulus of elasticity make necessary a few precautions in machining magnesium. For instance, the low modulus of elasticity results in some springing when parts are chucked or clamped too tightly. For this reason reamers, taps and drills are provided with slightly over-sized diameters to anticipate spring-back of the machined hole. Low heat conductivity makes



These tools are typical of those used for turning magnesium.

valuable the use of tools with more widely spaced teeth than other metals so there is little or no change in dimensions due to expansion of the magnesium.

In all its forms magnesium provides chips that are well broken and do not obstruct the work or the cutting tools. Chip formation in machining magnesium has little relationship to speeds, rake angles, etc., depending primarily on the alloy, its condition and the feed.

Cutting Tools

Steel or brass cutting tools of standard design can be used on magnesium alloys, but modifications are desirable to take full advantage of the cutting characteristics of these alloys. There is considerable latitude in tool angles, but relief angles of from 7 to 12 deg. keep tool flanks from rubbing on work, and clearance angles should be somewhat larger than normally used for other metals to give more room for chips. Rake angles are most suitable if from 0 to 15 deg., but can be increased to cut down tool forces at some sacrifice in tool life. Likewise, smaller rake angles should be provided on carbide tools than on high-speed steel. Relatively small nose radii on tools helps improve surface finish and reduce chatter.

Carbon tool steel, high-speed steel and cemented carbides are used as tool materials, with the latter being preferred and high-speed steels next best. Life of high-speed steel tools is improved with high hardness and carbon content. Longevity is also achieved through surface hardening treatments or chromium plating.

Honing or lapping of cutting tools will increase their life because of smooth surfaces and sharp edges. First, however, the tools should be finish-ground with fine-grained wheels—100-grit aluminum oxide wheels for high-speed steel or 320-grit silicon carbide or 200- to 320-grit diamond wheels for cemented carbides.

Tools should not be run until no longer usable, but sharpened when they have become slightly dull. Such action maintains cutting edges and saves tool material in the long run. It is sometimes advisable to establish definite intervals on production work for tool replacement to achieve maximum efficiency.

Fire Hazard—Magnesium chips can be ignited if they are heated to the melting point, which sometimes occurs when fine chips are produced in finishing cuts at high speeds. Experts say that the fire hazard, when using sharp tools, only becomes serious when feeds of less than 0.001 in. and speeds in excess of 1,000 ft. per min. are used. Likewise, any sparks increase the possibility of fire.

Although cutting fluids are not necessary to a fine finish in machining magnesium alloys, their use eliminates the possibilities of fire due to the characteristics of magnesium.

Turning and Boring

Turning and boring of magnesium alloys is done with a wide range of speeds, feeds and depths of cut. Cuts as deep as 0.500 in. and feeds from 0.003 to 0.200 in. are used. Practically any depth of cut can be taken if the work is held properly. Heavy feeds provide a means of removing metal fast, but with some sacrifice in surface finish. Cutting speeds vary from 150 to 5,000 ft. per min. An often applied rule is to turn and bore magnesium alloys as fast as the machine tool and its fixtures and the work itself will permit.

Recommended Speeds, Feeds and Depths of Cut for Turning and Boring Magnesium

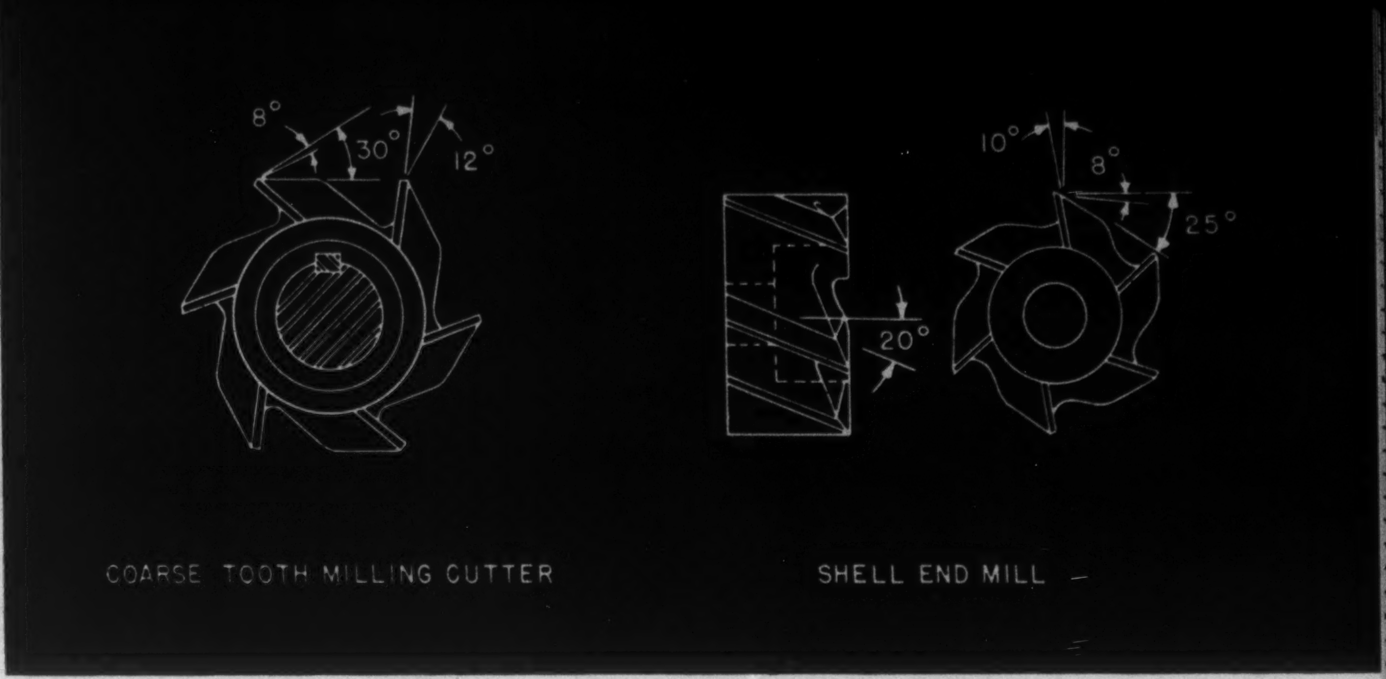
Operation	Speed Fpm.	Feed Ipm.	Maximum Depth of Cut In.
Roughing	300 to 600	0.030 to 0.100	0.500
	600 to 1000	0.020 to 0.080	0.400
	1000 to 1500	0.010 to 0.060	0.300
	1500 to 2000	0.010 to 0.040	0.200
	2000 to 5000	0.010 to 0.030	0.150
Finishing	300 to 600	0.005 to 0.025	0.100
	600 to 1000	0.005 to 0.020	0.080
	1000 to 1500	0.003 to 0.015	0.050
	1500 to 2000	0.003 to 0.015	0.050
	2000 to 5000	0.003 to 0.015	0.050

Shaping and Planing

These operations are usually at slow speeds so operational economies are achieved through heavy feeds and depths of cut. In taking heavy cuts on planers and shapers, care must be given to the possibility of inducing machining stresses in the work.

Milling

Milling is probably the one machining operation which can take full advantage of the machining advantages which magnesium offers. High-speed steel cutters are satisfactory in any milling cutter, but for inserted tooth face mills and fly cutters operating at high speeds cemented carbides are superior. Single and multiple tooth fly cutters work well for milling magnesium alloys. Only ½ to ⅓ the teeth needed for milling steel are required in slab, side cutting and straddle mills



Typical milling cutters of the type recommended for use on magnesium.

Recommended Speeds, Feeds and Depths of Cut for Milling Magnesium

Operation	Speed Fpm.	Feed In./Min.	Feed In./Tooth	Depth of Cut In.
Roughing	Up to 900	10 to 50	0.005 to 0.025	Up to 0.500
	900 to 1500	10 to 60	0.005 to 0.020	Up to 0.375
	1500 to 3000	15 to 75	0.005 to 0.010	Up to 0.200
Finishing	Up to 900	10 to 50	0.005 to 0.015	Up to 0.075
	1000 to 3000	10 to 70	0.004 to 0.008	0.005 to 0.050
	3000 to 5000	10 to 90	0.003 to 0.006	0.003 to 0.030
	5000 to 9000	10 to 120	0.002 to 0.005	0.003 to 0.030

used on magnesium. Face mills with inserted teeth should have large chip spaces to provide for removal of the large chip volume produced.

Face mills are sometimes provided with negative face rake angles to throw chips out of the cutter, and a helix angle of 45 deg. is desirable on helical slab mills.

Milling of magnesium alloys is done at speeds up to 9,000 ft. per min. These speeds do not result in fire hazards since the tool does not dwell or rub on the work. The full depth of cut can be taken in one pass, but for finish cuts the depth of cut should not be less than 0.003 to 0.004 in.

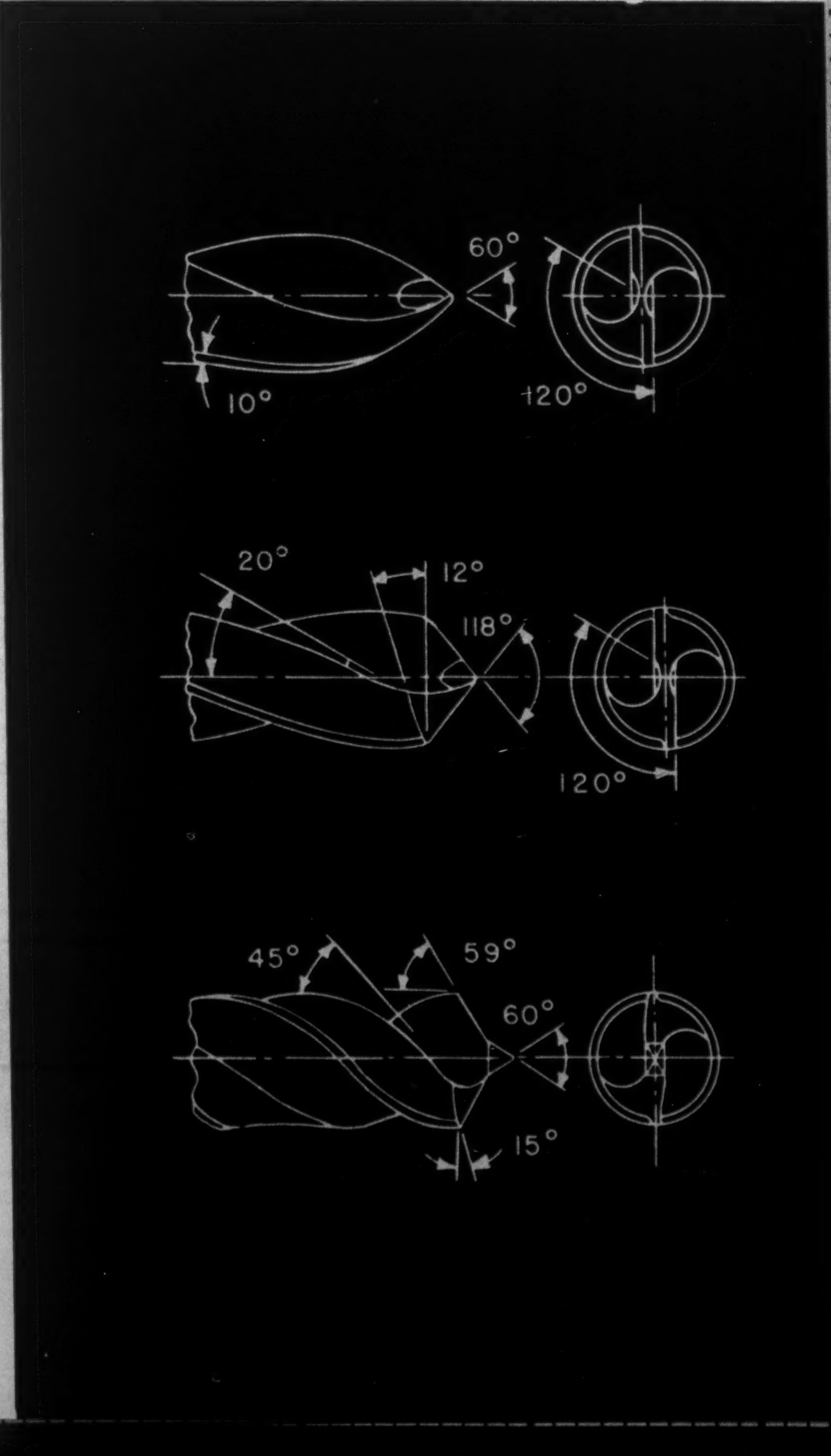
Drilling

Special designs of drills should be used for each of three types of drilling in magnesium. These types include sheet metal drilling, shallow hole drilling and deep hole drilling. Shallow holes can be drilled with standard drills, but modifications are in order for the other two types.

Sheet Drilling—To obtain accurate holes having good finish and a minimum burr in magnesium alloy sheet, the drill should have a point angle of about 60 deg. Such an angle prevents walking of the drill and reduces thrust. Edge angles should be from 120 to 135 deg. A 10-deg. helix will prevent the work from climbing the drill on the break-through.

Shallow Hole Drilling—Drilling holes in magnesium to a depth of less than five times the drill diameter requires only a few drill modifications. Although the standard helix angle of 25 deg. is satisfactory, it may vary from 10 to 30 deg. When low helix angles are used, the drill flutes should be highly polished to facilitate the flow of chips. Standard 118-deg. point angles and chisel edge angles of 120 to 135 deg. and a relief angle of about 12 deg. give effective action. Regardless of angles used, it is important that the drill always be sharp if the hole is to be satisfactory.

Deep-Hole Drilling—High-helix drills (40 to 45 deg.) handle satisfactorily the job of guiding large quantities of chips through a considerable length of flute involved in drilling deep holes. Flutes should be opened and



Drills for various types of holes, including sheet metal drill, shallow hole drill and a deep hole drill.

polished and the web should have a constant thickness. If these are not provided, chips are likely to jam resulting in a poor surface finish. High helix drills can penetrate to 25 times the drill diameter without withdrawal.

Chisel edge angles of 135 to 150 deg. are needed to give good surface finish. Angles outside this range cause difficulties due to improper relief at the cutting edge. The standard 118-deg. drill point angle is most satisfactory, but a pilot point will reduce spiralling.

Drilling can be done at maximum speeds available on drilling equipment. Generally, speeds used range from 75 to 400 ft. per min., but speeds to 2,000 ft. per min. could be used. Feeds should be heavier than when drilling other metals to give proper chip formation. An exception is small drills, which seem to work best with light feeds.

Reaming

As with milling cutters, reamers for use on magnesium alloys should have fewer flutes than normal. A general rule to follow is to provide four flutes on reamers under 1-in. dia. and six flutes on those of greater diameter. Flutes should be straight or have a negative helix angle of 10 deg. Recommendations for reamers include: rake angle, 5 to 8 deg.; relief angle, 4 to 7 deg., and clearance angle, 15 to 20 deg. In many cases a narrow margin (0.010 to 0.025 in.) is provided to avoid springing the metal, but this is not always necessary.

Normal feeds used for reaming steel or brass are satisfactory, although a wide range of feeds is permissible. The same is true of speeds. However, the cut should be fixed at about 1/32 in. on a dia. Cuts that are too light are likely to compress the metal, while heavy cuts may cause jamming of chips. Cutting speeds range from 100 to 400 ft. per min., with maximum speed generally being limited by the machine's capacity. The best combination seems to be high speed and medium feed.

Tapping and Threading

Tapping—Where tolerances are not too close, standard taps may be used on magnesium alloys, but high production and the tolerances required for class 3 and 4 threads require specially designed taps. Such taps are ground high-speed steel of the concentric type with straight or helical flutes. Tap recommendations include: rake angle, 10 to 25 deg.; heel rake angle, 3 to 5 deg.; chamfer, 2 or 3 threads; and narrow cylindrical lands. The use of a heel rake and elimination of radial thread relief provide cutting action when the tap is backed out, leaving a clean, accurately tapped hole. When taps cut oversize, the rake angle should be decreased. Increasing the rake angle will make a tap cut larger.

Mineral oil cutting fluids make easier the tapping of magnesium.

Threading—Cutting angles of threading dies should approximate those recommended for taps. Self-opening dies give maximum smoothness of threads. With the exception that the rake angle should be larger, cutting angles of thread chasers should parallel those used on turning tools. Chasing can be done at speeds up to 1,000 ft. per min.

Grinding

Finish grinding of magnesium alloys is seldom necessary, since machining will provide smooth, accurate surfaces. However, rough grinding is necessary in foundry work and to remove flash from forgings and die castings. Since magnesium is relatively soft, wheels of from 20 to 40 grit size and 40 to 70 are used, respectively, for rough and finish grinding.

Since grinding results in powdery particles of magnesium, precaution must be taken against this flammable dust and the dust should never be allowed to accumulate.

Forming and Bending

Magnesium alloy AZ31X, AZ61X and M1 are used for formed parts. When in the annealed condition these alloys can be hot formed at temperatures up to 650 F.

Magnesium alloy sheet can be blanked, punched and sheared with much the same equipment and by the same general methods as are used for other metals. The important exception is that forming is usually done at elevated temperatures. Hot forming permits deep draws in one operation and makes unnecessary provisions for spring back in the sheet.

Shearing and Blanking

A rough, flaky fracture results on the edges of sheared and punched magnesium sheet in thickness above 0.064 in. The following of recommended practice as regards shear and clearance angles and clearances will minimize this rough fracture surface.

Shearing—In shearing there should be as little clearance between blades as is possible without scoring them. Clearance of 3 to 5% of the sheet thickness is the maximum. The upper shear blade should have a shearing, or rake, angle of 30 to 45 deg. Heavy sheet and plate should be hot-sheared at 600 F for annealed stock and at from 275 to 400 F for hard rolled material, depending upon the alloy. Dimensional allowances must be made in hot shearing since the alloys will shrink some on cooling.

Blanking and Punching—Here again small clearances are desirable. Clearance should be limited to 3 to 5% of sheet thickness in sizes over 0.065-in. thick. Clearance angles should be great enough to permit punchings to be removed and to minimize binding of the punch. Shear angles are so located as to provide the best quality on the edge which requires a superior finish. The shear angles are from 2 to 3 deg.

Blanking and punching normally is done cold, since shrinkage of the heated sheet on contacting the cold punch might cause adherence of the sheet to be punched.

Forming

Although both hydraulic or mechanical presses can be used for drawing magnesium alloys, hydraulic presses have the advantage of controllable speed during the drawing operation. A further consideration is the uniform application of pressure which is desirable. Double or triple action presses are best suited to drawing magnesium alloys.

Drawing Dies—Dies do not differ greatly from those used on other materials except that provision must be made for them to be heated. Generally mild steel dies highly polished and amply lubricated prove satisfactory. The die stock has to be thick enough to withstand the hold down pressures required and to resist warpage at the temperatures involved. The male die, or punch, can be of welded or cast steel, cast iron, aluminum or magnesium.

Since the coefficient of thermal ex-

Forming Temperatures for Magnesium Alloys

Alloy	Condition	Working Temperature Range—Deg. F
AZ31X	Annealed	400 to 500
AZ31X	Hard Rolled	275 or 300 Max.*
AZ61X	Annealed	550 to 650
AZ61X	Hard Rolled	400 Max.
M1	Annealed	550 to 650
M1	Hard Rolled	400 Max.

300 F may be used if metal is at temperature 15 min. or less.

pansion of magnesium alloys is about hree times that of steel, steel dies for ot forming must be made oversize to btain the proper size of part. The ame is true of aluminum dies.

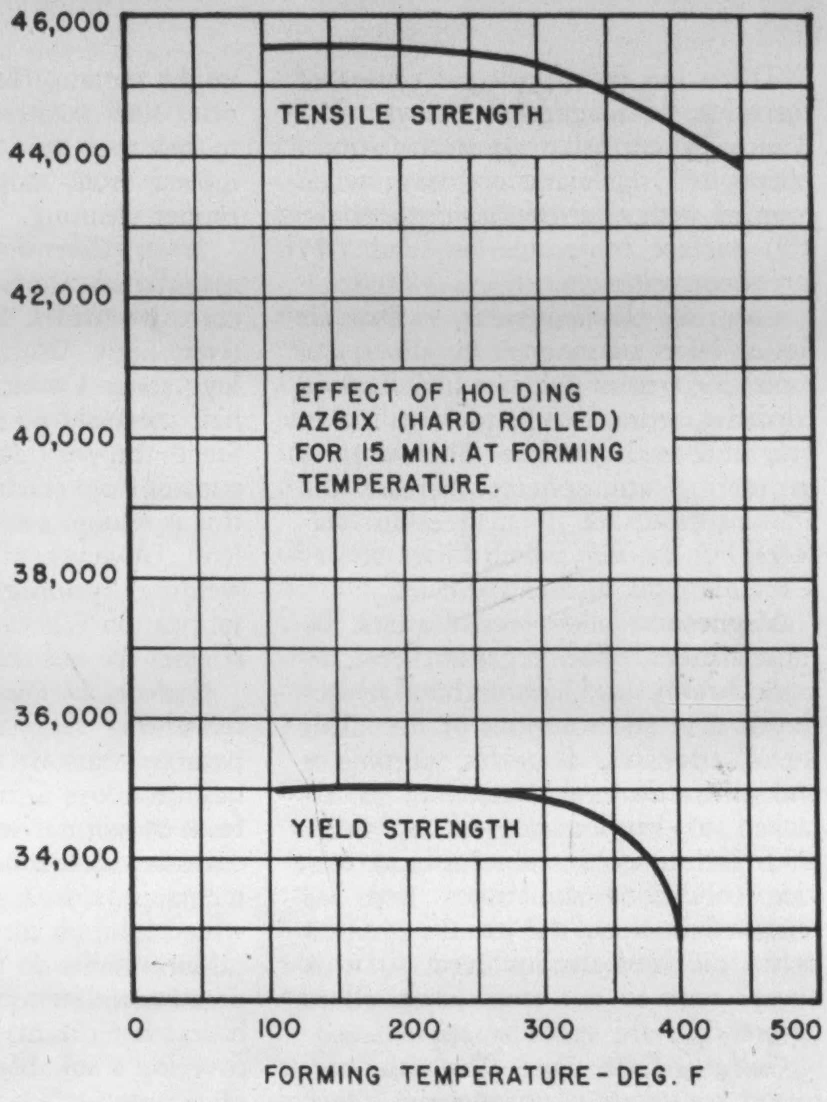
Forming dies are usually heated with utomatically controlled gas burners. Electrically heated dies, which are highly satisfactory, are less frequently used because of designing odd-shaped heating units.

Lubricants—Both the sheet and the die surfaces must be well lubricated before drawing to prevent scoring or galling of the part and pick-up on die surfaces. Colloidal graphite, suspended in a suitable carrier, is ideal for magnesium sheet. It can be applied by spraying. Die surfaces can have a mixture of 20% graphite and tallow buffed on. Caution should be observed to insure use of a lubricant that can be easily removed from the sheet surface. For instance, colloidal graphite should only be used with sheet that is supplied in the oiled condition.

Deep Drawing

Magnesium sheet which is to be hot formed is first preheated to working temperature by any convenient method. The Guerin process is widely used in forming magnesium sheet, where only relatively shallow forming or pressing is involved.

Deep drawing of such parts as cylindrical cups to a depth 1.5 times their diameter in a single draw is not uncommon in hot forming magnesium.



Such a draw means a reduction of 60 to 65%.

Pressure pads, in drawing magnesium, are used to impart only enough pressure to prevent wrinkling. Too much pressure can result in thinning out of the sheet and possibly rupture. Shims between the clamping surfaces help reduce the pressure. No set clamping pressures can be stated, since all jobs differ.

On small parts with deep draws it is sometimes advantageous to cool the punch. This permits the sheet to be drawn over the draw ring radius at its maximum plasticity and be chilled immediately thereafter, thereby increasing its tensile strength.

Spinning—In spinning magnesium sheet, parts with only small deformation can be spun cold, but all others, where forming is severe, must be spun hot. The sheet is heated to between 500 and 600 F, preferably by torch applied while the stock is rotating. The metal, of course, must be lubricated—with laundry soap or a similar material.

Maximum Temperatures for 1-Hr. Baking Schedules on Magnesium Alloys

Alloy	Form	Condition	Maximum Baking Temp. Deg. F
AZ92	Sand Cast	Heat Treated	350
AZ92	Sand Cast	Heat Treated	350
A10	Sand Cast	Heat Treated	350
AZ80X	Extruded	As Extruded	350
AZ80X	Forged	As Forged	350
AZ61X	Sheet	Hard Rolled	350
M1	Sheet	Hard Rolled	350
AZ31X	Sheet	Hard Rolled	260

Other alloys are unaffected at the usual temperatures and times employed for baking paint systems.

Cleaning and Finishing

Despite a once prevalent belief to the contrary, magnesium alloys show high surface stability under ordinary atmospheric conditions. Their stability is due to their high purity. Nickel, iron and copper—impurities in magnesium alloys—tend to reduce corrosion resistance and so are kept to a minimum in standard alloys.

There are four principal causes of corrosion of magnesium alloys: (1) Attack by corrosive agents or atmospheres; (2) galvanic corrosion when coupled with electropositive materials; (3) surface contamination; and (4) stress corrosion.

Corrosive Environments—Dry air has no effect on magnesium alloys, and moist air free of salt has little serious corrosive action except to form a thin gray film on the surface. The chlorides in marine atmospheres increase the amount of attack on magnesium surfaces, but the film which forms acts as a retardant to further corrosion.

Magnesium alloys resist attack by most alkalies, many organic chemicals, pure chromic acid, concentrated hydrofluoric acid and solutions of the alkali metal arsenates, fluorides, chromates and dichromates. Magnesium is attacked to varying degrees by other acids and aqueous salt solutions. Service conditions sometimes have as much effect upon the metal's reaction as do the medium involved, so it is always wise to test magnesium alloys before they are specially applied.

Galvanic Corrosion—While the corrosion resistance of magnesium alloys is satisfactory for a wide variety of services, there is a great problem in galvanic corrosion caused by coupling magnesium alloys with any of several metals which are electropositive to magnesium. Steel, copper and brass, among the commonly used engineering materials, are all electropositive to magnesium in the presence of an electrolyte, in the form of any heavy moisture. Under certain conditions, magnesium alloys in contact with each other set up a galvanic couple. Although not a galvanic action, magnesium in contact with wood results in corrosion difficulties when moisture is present. Thus, to lessen the possibility of corrosion, where magnesium is involved, moisture must be kept from entering joints where metals or magnesium and wood are in contact.

Surface Contamination—Dirt and various foreign materials on the surface of magnesium impair the corrosion resistance of magnesium alloys, since such particles can form galvanic cells in the presence of moisture.

Contaminants can be imbedded in magnesium alloys by such processing operations as stamping and forming or handling, where steel particles can be attacked; cleaning with steel wool, wire brush or emery cloth other than aluminum oxide; sand, shot or grit blasting; and, gas welding, where flux might remain. Thus, after any operations such as these care must be taken to see that any contaminants are removed from magnesium surfaces by proper cleaning.

Stress Corrosion—Undue stress of magnesium alloys in the presence of corrosive media. Stresses must be relatively high. With most magnesium alloys, stresses which exceed about one-half the yield point will cause trouble. Since proper design keeps service stresses from reaching the danger point, this is seldom a serious corrosion problem. However, stresses set up during welding, forming and other steps in fabrication can cause service failure if stresses are not relieved.

Corrosion Prevention—Chemical treatments and certain recommended paint systems are used to protect magnesium alloys against the corrosive effects of normal weathering and many corrosive atmospheres. Chemical treatments provide a passive surface layer which inhibits corrosion. Most chemical treatments do not furnish complete protection, but serve primarily as paint bases. For the majority of uses paints, covering a suitable prime coating, supply ample surface protection.

Machined or other finished parts which are to be stored before use are often protected in storage by means of a thin coating of oil. A satisfactory oil is 600 W mineral oil thinned with kerosene. Where storage is under severe conditions, oils containing inhibitors are used. Protective oils can be removed by any of several standard cleaning procedures.

It is difficult to establish hard and fast rules to prevent contact corrosion because of the many variations involved. Part of the difficulty can be minimized by a proper selection of materials. Under corrosive conditions, Alloy M1 is more subject to galvanic corrosion than other magnesium alloys. In cases where magnesium to magnesium contacts are involved, it is desirable to use alloys of similar composition. Alloy M1 is mildly attacked if coupled with other magnesium alloys in a galvanic circuit. Aluminum alloy rivets other than 56S will cause corrosion of magnesium alloys in the presence of an electrolyte.

Several precautionary measures are possible to prevent contact corrosion, such as chemical treatments and primer coats on faying surfaces; caulking compounds; insulating substances, plus overall painting of the complete assembly.

In addition to annealing as protection against stress corrosion, the surfaces can be painted or otherwise protected.

Cleaning

As has been pointed out, one of the most serious causes of corrosion in magnesium alloys is the presence of surface contamination. Therefore, cleaning is essential to all steps in magnesium fabrication, in many cases both before and after fabricating steps. The four types of cleaning used in cleaning magnesium alloy surfaces are: solvent cleaning, alkaline cleaning, acid pickling, and mechanical cleaning. Choice of method depends upon the job to be done.

Solvent Cleaning—To remove oily matter from magnesium surfaces, these surfaces can be washed with organic solvents or subjected to vapor degreasing. Most chlorinated solvents, alcohol and similar grease solvents can be used without harm to the magnesium, as can the emulsion type cleaners.

Solvent cleaners are used both to remove superfluous amounts of oily matter prior to alkaline cleaning and as a cleaning step prior to painting.

Alkaline Cleaning—Akaline cleaning is most satisfactory for degreasing magnesium since it removes both the oily matter and previously applied chemical treatments. Alkaline cleaning solutions should have a pH value above 11 for most satisfactory results. After cleaning by alkaline methods, thorough rinsing is necessary to prevent contamination of chemical treatment baths.

Acid Cleaning—For difficult cleaning jobs such as those involving oxide layers, burned-on lubricants which cannot be removed by other cleaning methods, acid cleaning can be used. Cleaning in a chromic acid solution is most satisfactory, since this acid does not attack magnesium, but does dissolve oxides and hydroxides usually present. When burned-on graphite-base forming lubricants are to be removed, calcium or magnesium nitrate is added to the chromic acid solution in the ratio of 4 oz. per gallon. Parts to be cleaned remain in the solution 1 to 15 min. at a bath temperature of 190 to 212 F. The chromic acid bath should maintain a pH range of 0.5 to 2.

Parts which have been sand, grit or shot blasted should be pickled sufficiently to remove 0.002 in. or more of surface. The pickling baths should consist of 3 parts of concentrated sulfuric cid in 97 parts of water (by volume). The pickling time is 10 to 15 sec. at oom temperature. Such treatment is atisfactory for all alloys except as cast r aged alloy AZ92. Here a pickle of parts concentrated nitric acid, 2 parts oncentrated sulfuric acid and 90 parts ater should be used. Pickling should recede machining, since the metal emoved in these baths might exceed achining tolerances.

Mechanical Cleaning—Casting skin, irt, oxide and similar superfluous coatngs can be removed by sand, grit and hot blasting, although these methods re not as satisfactory on magnesium lloys as wire brushing or sanding. When any of the blast methods are sed, acid pickles are required to obtain aximum corrosion protection.

Finishing

Chemical Treatments — Protective hemical treatments result in a passivating layer on the surfaces of magnesium alloys. Such coatings resist corrosive attacks and act as bases for paint coatings.

Chrome-Pickle—Much of the magnesium furnished by suppliers is protected with a chrome-pickle treatment. This treatment is also used by fabricators after mechanical cleaning as a touch-up. Since a chrome-pickle removes up to 0.0006 in. of metal, it should not be used on machined surfaces, unless proper allowances have been made. Magnesium parts which contain inserts of brass or steel can be treated by the chrome-pickle method, but polished steel surfaces should be protected by a thin film of lacquer.

Dichromate — A dichromate treatment can be used on magnesium alloys except M1 with a resultant increase in resistance to corrosion by salt water. This treatment results in no appreciable dimensional changes so can be applied after machining and before painting. Dichromate has no effect on steel, brass, bronze or cadmium plate, so castings and other parts containing these metals can be treated. Aluminum, however, is attacked by the hydrofluoric acid bath, which is part of the process. Dichromate coatings will vary in color from dark brown to black, depending on time of treatment, condition of the bath and the alloy composition. Dichromate treatments provide good paint bases for all types of exposure.

Galvanic Anodize—This treatment is used on alloy M1 instead of the dichromate treatment previously described. Galvanic anodizing can be used on all other alloys, with much the same effect as the dichromate, *i. e.,* no dimensional change, dark color, satisfactory paint base.

Sealed Chrome-Pickle—This treatment is best suited to wrought alloys. Parts to be given this treatment are first given a chrome-pickle and then boiled for 30 min. in a bath containing 10 to 15% sodium dichromate. A sealed chromate-pickle is in effect a treatment combining the chrome-pickle and dichromate methods.

Painting

After making certain that the magnesium surface to be painted has been cleaned properly and then provided with a suitable chemical treatment to serve as a paint base, it is necessary to choose a suitable primer and then the proper finish coat that is compatible with the primer. Any choice of painting material is based first on the exposure surface it must endure. In other words, is the surface to be exposed to indoor use, outdoor use or marine atmospheres?

For *indoor service,* the magnesium should be given a chrome-pickle, one coat of primer and one or more finish coats. *Outdoor service* is best prepared for by use of a chrome-pickle, dichromate or galvanic-anodize treatment, followed by a chromate primer and two or more coats of a suitable finish coat. *Marine atmospheres* require a dichromate, galvanic-anodize or sealed chrome-pickle treatment, one coat of suitable chromate primer and three or more finish coats.

Primers—Primers must have good adhesion, and, if marine atmosphere exposure is anticipated, should be inhibitive. This latter characteristic is best obtained with zinc yellow pigment. Zinc yellow primer is the most commonly used, but it is necessary that the pigment be of high purity as far as chloride and sulfate content is concerned. Zinc yellow primer should be applied in thin coats, about 0.0005-in. thick, and two coats be used for maximum inhibitive value.

Surfacers are sometimes used on certain types of products, but since they tend to induce brittleness in the coatings they are generally avoided. A relatively high degree of smoothness can be obtained by sanding between regular finish coats.

Finishes—Finishing materials must be compatible with the primers used. Quick drying lacquer or synthetic resins are generally chosen rather than oil type paints. Lacquers used on magnesium include formulations based on cellulose compounds or on butyrates, proprionates and their aceto derivatives.

Generally, finish coats are chosen on the basis of: compatability with the primer; adaptability to the conditions and to finishing equipment available; and ability to provide necessary protection under anticipated exposure conditions.

One coat of paint, for the purpose of recommendations for painting magnesium, is limited to a thickness of 0.001 in. Thus, where two or three coats are recommended these should be understood to be in multiples of one mil.

Painting Procedures—Standard finishing procedures are followed with magnesium. The Army and Navy have approved methods which should be used for aircraft work, while the standard practices for automotive work are satisfactory for such work as truck and trailer bodies.

Baked Finishes—Black japan and color coats are available in lusters ranging from flat to high glass. They should be applied over baking type primers. Baked coatings provide excellent adhesion, maximum imperviousness and good wear resistance. Baking of finishes on magnesium alloys can be done in ovens or by means of infra-red lamps, but precautions must be observed lest the mechanical properties of certain alloys be effected. Alloy AZ80X either extruded or forged, heat treated castings and hard rolled sheet can be affected, as far as mechanical properties are concerned, by the temperatures customarily used for baking finishes.

Special Finishes—Novelty finishes of a durable nature are sometimes desired to add sales appeal to certain types of magnesium products. Many novelty finishes are self-performing and provide crystallized, cracked, checked, wrinkled, hammered, leather and other effects. Often these finishing materials can be applied without the preliminary surfacing and sanding often required, since they have a natural roughness to attain their effect. Transfer and direct methods can be used to apply reproductions of almost any surface on magnesium articles.

Clear Finishes—Chemically colored or buffed magnesium surfaces require a clear coating to protect them against wear and tarnish. For such protection, one to three coats of an approved clear lacquer should be used. Standard plating lacquers are suitable for electroplated magnesium parts.

Rubber Coatings—Where the type of part requires it, both hard and soft rubber coatings can be attached to magnesium. Since these procedures are rather special, the magnesium producers generally like to make specific recommendations when all details of the job are known.

Electroplating — Magnesium alloys can be electroplated. Adherent nickel deposits are obtained and these, in turn, can be plated with cadmium, chromium and zinc. After cleaning and buffing the part is dipped in a chromic-nitric acid solution, followed by a hydrofluoric acid-nitric acid dip. Double pickling provides a surface with a fine etch, free from contaminating chromium ions, to which nickel will adhere. The plating is done in a nickel borofluoride bath containing slight excesses of boron and fluorine. Standard cyanide and acid baths are used for plating with the other metals.

Design Considerations

Structural magnesium alloys differ in many important physical properties from other generally used engineering materials, each of which has an influence on its selection. The most important characteristics will be discussed here.

Specific Gravity—The weight per cu. in. of structural magnesium alloys varies between 0.064 and 0.067 lb. The strength-weight ration of magnesium is one of the chief advantages of these alloys, particularly in transportation equipment, parts subjeet to frequent, rapid changes in position and in many types of portable equipment.

Strength—Unlike mild steel, magnesium alloys exhibit a gradual yielding when stressed. No true proportional or elastic limit can be given for these alloys, rather, the yield strength is defined as the stress at which the stress-strain diagram deviates 0.2% from the modulus line.

Modulus of Elasticity—Magnesium alloys have an accepted modulus of elasticity of 6,500,000 psi., about 2/3 that of aluminum and ¼ that of steel. In many castings this makes little difference, but where designs are controlled by stiffness requirements the low modulus must be taken into account. Stiffness can usually be increased by small increases of cross section, preferably in depth, since stiffness increases most rapidly with depth of the member. In resilience, or capacity for elastic shock absorption, the low modulus of elasticity makes magnesium alloys excel. The modulus of rigidity or modulus of shear of magnesium alloys is approximately 2,400,000 psi.

Endurance Limit—Magnesium alloys are somewhat more sensitive than other metals to the effect of notches and other stress raisers which reduce their endurance strength considerably. Therefore, in highly stressed structural parts, notches and sharp corners are to be avoided if possible. Ample fillets and beading holes should be provided, and by blending and reinforcing transitions of stress-carrying sections, the good fatigue properties of the metal can be fully utilized.

Hardness and Wear Resistance—For applications involving severe abrasive conditions, magnesium alloys must be protected by inserts or liners of such materials as steel or bronze, particularly where there is no lubrication and where high temperatures are anticipated. Inserts can be cast in or attached by various means. In cases where there are light loads, slow speeds and pressure lubrication, extremely hard steel shafts, highly polished, can be run directly in magnesium alloy bearings.

Heat and Cold Properties—At 200 F and above the yield strength of magnesium alloys drop appreciably and the values of elongation are higher than at room temperature. At temperatures down to −110 F there is little significant change in properties, except a slight increase in yield strength and a slight reduction in elongation.

Thermal Properties—In the temperature range of 65 to 212 F the mean coefficient of thermal expansion of magnesium alloys is about 0.0000145 per deg. F. Allowances must be made in designs for the thermal expansion differential between magnesium and other members if the assembly involves dissimilar metals and wide temperature variations are anticipated.

The mean specific heat of magnesium alloys is 0.249 calories per gram per deg. C. Thermal conductivity varies with the alloy. Alloy M1 has the highest value, 0.30 c.g.s. Increasing precentages of alloying elements reduces conductivity down to 0.16 c.g.s. units in the most highly alloyed alloy. In considering and comparing specific heat and thermal conductivity of magnesium alloys with those of other metals, it must be remembered the magnesium cross-sections are frequently somewhat increased over those of other metals. Such increases will affect the relative thermal behavior of structural members of the various members.

Electrical Conductivity—On a volume basis, magnesium alloys have electrical conductivity values ranging from 10 to 34% of that of copper.

Dimensional Stability—Some magnesium alloys are subject to slight permanent growth at temperatures in excess of 200 F for any length of time. Maximum permanent growth of the alloys is only achieved at high temperatures for extended periods. Only a fraction of the maximum growth values will be effective under normal operating conditions.

Principal Producers of Magnesium Alloys

Wrought Alloys

Amco Magnesium Corp., New York
American Magnesium Corp., Pittsburgh
Apex Smelting Co., Chicago
Basic Magnesium, Inc., Las Vegas, N. M.
Diamond Magnesium Co., Painsville, Ohio
Dow Chemical Co., Magnesium Div., Midland, Mich.
National Standard Co., Niles, Mich.
New England Magnesium Co., Inc., Malden, Mass.
Permanente Metals Corp., Oakland, Calif.
Revere Copper & Brass, Inc., Aluminum & Magnesium Div., New York
Rigid-Tex Corp., Buffalo, N. Y.
White Metal Rolling & Stamping Corp., Brooklyn

Casting Alloys

Advance Pressure Casting Co., Brooklyn
Aluminum & Magnesium, Inc., Sandusky, Ohio
American Magnesium Corp., Pittsburgh
Apex Smelting Co., Chicago
Dow Chemical Co., Midland, Mich.
Eclipse - Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.
Hills-McCanna Co., Chicago
L. E. Mason Co., Hyde Park, Mass.
Mt. Vernon Die Casting Corp., Mt. Vernon, N. Y.
National Smelting Co., Cleveland
New Products Corp., Benton Harbor, Mich.
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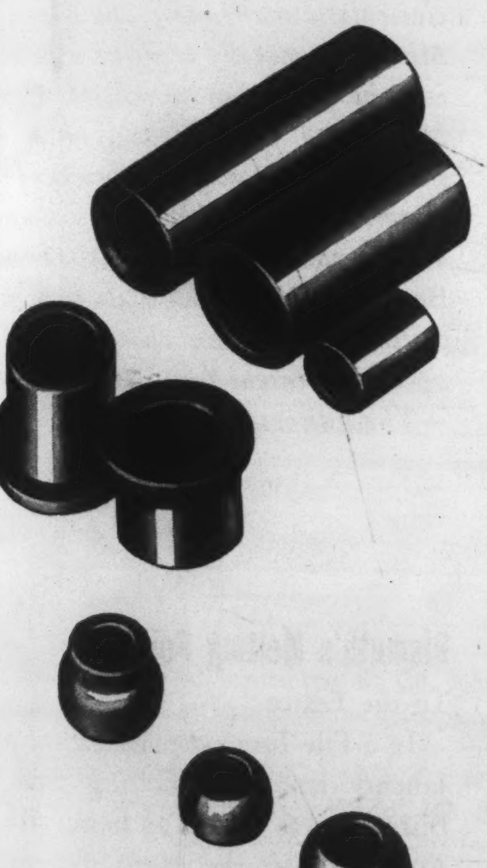

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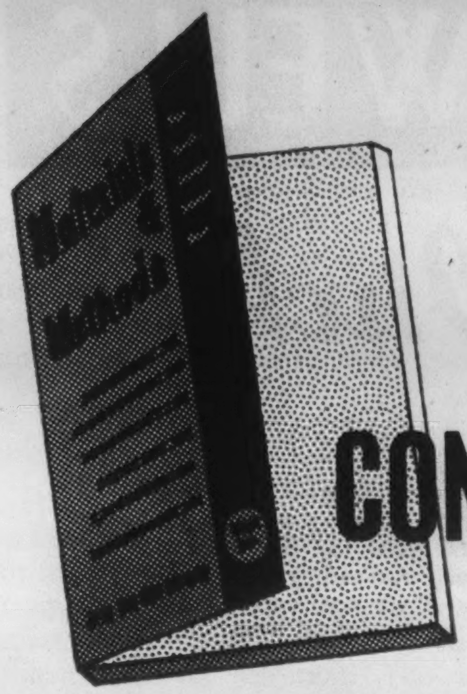


CONTENTS NOTED

Manganese Production

To the Editor:

On page 93 of the January MATERIALS & METHODS there is a statement which reads: "The development of electrolytic production of manganese by the U. S. Bureau of Mines has provided a pure manganese, promoting better alloys of which manganese is a component."

The author of this misstatement is apparently blissfully unaware that at Knoxville, Tenn., there is an operation of the Electro Manganese Corp. which to date has produced well over 14 million lb. of electrolytic manganese.

The original plant was presumably designed by some of the Bureau of Mines personnel and approximately a quarter of a million dollars went into the venture, which was a complete operating failure. Additional large sums were put into development and plant and, as evidenced by a considerable number of patents, eventuated in a distinct process quite apart from any operation of the Bureau of Mines. I am sending you enclosed a copy of a table of production of electrolytic manganese, showing the production of the Electro Manganese Corp. and the Bureau of Mines, taken from the *Minerals Year Book, 1945,* on the chapter on manganese. This might be useful in comparing the development of the metal. The chart indicates that the Electro Manganese Corp. produced well over a million and a half lb. of manganese metal prior to the commencement of production at the Boulder City plant of the Bureau of Mines.

It was manganese from the Electro Manganese Corp. plant that supplied the Mint with its needs for the copper-silver-manganese alloy for the coinage of the five-cent piece; it was manganese from the Electro Manganese Corp. which was the metal provided in lend-lease to the British, these two amounts being of the order of a total of 150,000 lb. monthly over a considerable period.

It does not appear to be in line with the facts to allow the statement "The development of the electrolytic production of manganese by the U. S. Bureau of Mines . . . " to go unrefuted, particularly when a comparison of the procedure employed by the Bureau of Mines at Boulder and the patents of the Electro Manganese Corp. permits interesting conclusions to be drawn.

C. L. Mantell,
Consulting Engineer

Electro Manganese Corp.,
New York, N. Y.

The figures referred to indicate that in 1945 Electro Manganese Corp. produced 3,398,569 lb. of manganese as compared to a production of 280,336 lb. by the Bureau of Mines. In the matter of the development o electrolytic manganese, the Bureau o Mines is generally credited with making the first laboratory start. Electro Manganese Corp. developed an entirely different method, produced the material and marketed it commercially for some years before the bureau. Bureau of Mines publicity leaves the distinct impression that they developed the present commercial product. —The Editors.

Bismuth's Melting Point

To the Editor:

In a File Fact on page 123 of your January issue the melting point of Bismuth was stated as being 418 F. According to the latest Bureau of Standards tests, the melting point is 520 F.

Walter C. Smith,
Metallurgist

Cerro de Pasco Copper Corp.,
New York, N. Y.

Our thanks to reader Smith for supplying us with this correct figure. The error, of course, was typographical, since at no time—at least in recent years—has the melting point been given as less than 519.8 F.—The Editors.

MATERIALS & METHODS Engineering File Facts

NUMBER 140
May, 1947

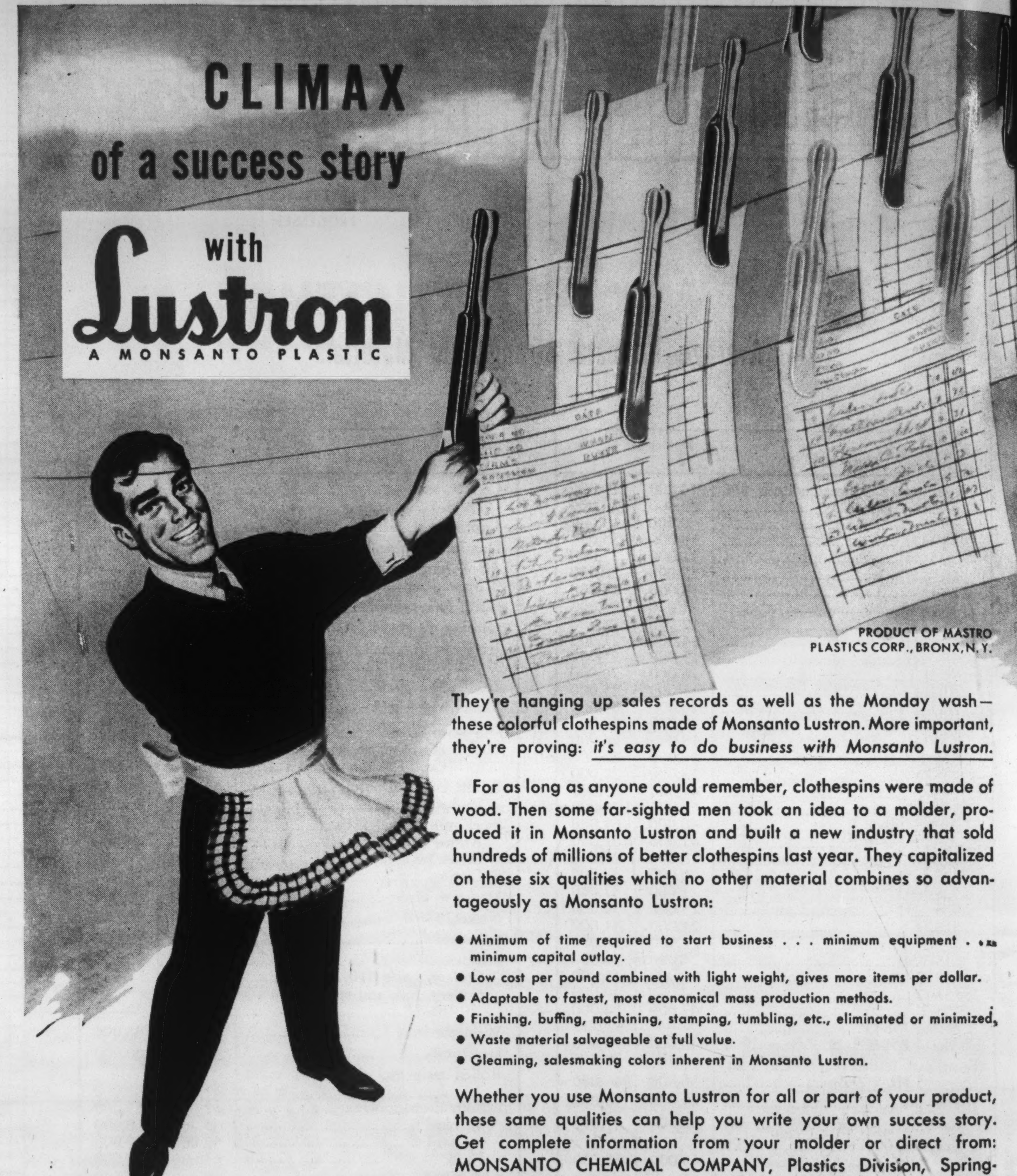
MATERIALS: .... General
PROCESSES: .... Forming

Average Ultimate Strength of Materials

Material	Shear, Psi.	Tensile, Psi.
Aluminum, sand cast, silicon 5%	14,000	19,000
Die cast, silicon 5%	22,000	29,000
2S-O	9,600	13,000
2S-¼H	10,000	15,000
2S-½H	11,000	17,000
2S-¾H	12,000	20,000
2S-H	13,000	24,000
3S-O	11,000	16,000
3S-¼H	12,000	18,000
3S-½H	14,000	21,000
3S-¾H	15,000	25,000
S3-H	16,000	29,000
Alclad 14S-O	18,000	25,000
Alclad 14S-W	40,000	64,000
Alclad 14S-T	42,000	69,000
17S-O	18,000	26,000
17S-T	36,000	62,000
24S-O	18,000	27,000
24S-T	41,000	68,000
24S-RT	42,000	73,000
Alclad 24S-T	40,000	64,000
Alclad 24S-RT	41,000	67,000
52S-O	18,000	29,000
52S-¼H	20,000	34,000
52S-½H	21,000	37,000
52S-¾H	23,000	39,000
52S-H	24,000	41,000
61S-O	12,500	18,000
61S-W	24,000	35,000
61S-T	30,000	45,000
75S-O	——	40,000
75S-T	47,000	88,000
Alclad 75S-O	——	32,000
Alclad 75S-T	46,000	76,000
Brass, cast, leaded red, 85 Cu, 5 Sn, 5 Pb, 5% Zn	36,000	46,000
Die cast	45,000	55,000
Cartridge, 70 Cu, 30% Zn, soft	32,000	47,000
Forging, 60 Cu, 38 Zn, 2% Pb soft	48,000	60,000
Rolled strip and sheet, 65 Cu, 35% Zn, soft	32,000	46,000
¼ hard	40,000	59,000
½ hard	44,000	65,000
¾ hard	47,000	72,000
Hard	50,000	78,000
Extra hard	54,000	84,000
Spring	57,000	95,000
Britannia metal	9,000	8,000
Bronze, phosphor, grade A, sheet, annealed	40,000	55,000
Spring temper	65,000	105,000

Material	Shear, Psi.	Tensile, Psi.
Copper, soft	24,000	32,000
Hard	37,000	55,000
Cupronickel, 80 Cu, 20% Ni, soft	35,000	48,000
Duralumin, annealed	20,000	28,000
Fibre, hard	24,000	——
Vulcanized	13,000	15,000
Gold, 14 carat, soft	42,000	58,000
Gilding metal, 95 Cu, 5% Zn, soft	25,000	35,000
Iron, cast	25,000	22,000
Cast, malleable	48,000	54,000
Lead	3,500	5,000
Monel metal, soft	50,000	70,000
Nickel	53,000	68,000
Nickel (German) silver, 18 Ni, 65 Cu, 17% Zn, soft	35,000	58,000
Silver, sterling, soft	27,000	37,000
½ hard	45,000	65,000
Steel, mild	50,000	60,000
Armco Iron, annealed	40,000	45,000
Boiler plate	55,000	70,000
Casting	60,000	70,000
Hacksaw blade	78,000	105,000
Nickel, 3½%	70,000	85,000
Silicon	60,000	72,000
Stainless, 18:8	75,000	95,000
Cutlery, knife 410, full hard	145,000	——
Cutlery, fork and spoon, 420 ¼ hard	65,000	——
Wrought iron	40,000	48,000
Structural	45,000	60,000
Rolled strip and sheet, soft, extra deep drawing	41,000	48,000
Soft, deep drawing	42,000	53,000
¼ hard	45,000	60,000
½ hard	50,000	72,000
Hard	61,000	92,000
SAE, 1010, cold-rolled	42,000	56,000
1015, cold-rolled	50,000	67,000
1020, cold-rolled	52,000	69,000
1025, cold-rolled	60,000	80,000
1030, cold-rolled	63,000	85,000
1040, cold-rolled	73,000	100,000
1050, cold-rolled	82,000	110,000
1075, hot-rolled	78,000	103,000
1095, hot-rolled	80,000	106,000
Tin, block	4,000	5,000
Zinc, commercial	19,000	23,000
Drawing	16,000	20,000

This table is based upon physical experiments conducted in the laboratories of E. W. Bliss Co.



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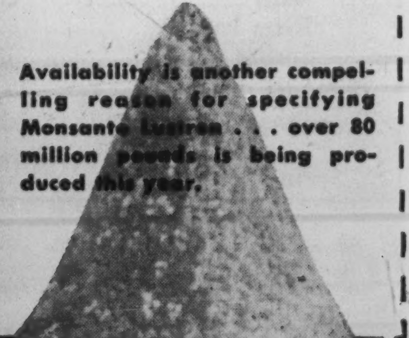

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MATERIALS & METHODS Engineering File Facts

NUMBER 141
May, 1947

MATERIALS: .... Aluminum Alloys

Properties and Fabrication of Aluminum Alloys

Metals Compared	Approx. Melt. Pt. in Deg. F	Wt. in Lb. Per Cu. In.	Wt. in Lb. Per Cu. Ft.	Approx. Ratios Aluminum = 1					
				Weight Ratio	Spec. Heat Ratio	Latent Heat Ratio	Thermal Conduct. Ratio	Expansion Ratio	Modulus in Millions
Aluminum	1215	0.098	170	1.0	1.0	1.0	1.0	1.0	10
Magnesium	1204	0.063	109	0.65	1.1	0.75	0.40	1.1	6.3
Beryllium	2345	0.066	114	0.67	1.9	3.6	0.74	0.5	42.7
Copper	1980	0.323	560	3.3	0.40	0.55	1.70	0.72	16
Steel	2700	0.284	490	2.9	0.48	0.70	0.30	0.50	30
(18:8) Stainless	2600	0.286	495	2.9	0.53	0.70	0.07	0.67	30
Nickel	2646	0.322	560	3.3	0.57	0.79	0.27	0.54	30

Precautions — Aluminum and Aluminum Alloys

General

Aluminum melts just at the beginning of the visible "color" range of temperature; therefore, all fabrication steps are in the "black heat" range. Temperature control is essential.

Forging

Aluminum must not be forged above 900 F; otherwise cracking, burning, blistering may take place.

Aluminum should not be forged below 400 F. Aluminum requires about the same power in forging as ordinary steel.

Aluminum cools much more rapidly than steel (ratio of conductivities 3 to 1). Power required for forging increases with drop in temperature. Danger of cracking increases as temperature is lowered.

Forging or pressing dies should not be used without proper preheat. Control of preheat is necessary. One authority states: "Use of cold dies is probably the greatest cause of die breakage." Too high a preheat temperature may draw the temper of the die and shorten die life. Preheat dies to 250 to 400 F.

Forming

Aluminum may crack if forming is done at room temperature. Preheating metal to 300 to 400 F is important. Dies should also be preheated to 250 to 400 F.

Welding

Preheating is strongly recommended because of the high heat conductivity of aluminum. Do not preheat above 800 F; otherwise there is danger of approaching the burning range. Preheat an area of base metal for some distance on either side of the seam. Preheating minimizes contraction strains. Consult the manufacturers of aluminum for welding details.

Miscellaneous

In friction soldering, aluminum must be preheated to 550 to 800 F to remove oxide film.

Compilation by courtesy of the Tempil Corp., New York

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Edited by H. R. CLAUSER

The Centrifugal Casting of Brass Ingots for Cold Rolling

Condensed from "Metallurgia"

An investigation to determine the feasibility of cold rolling brass from centrifugal cast rings was conducted. A centrifugally cast ingot has the shape of a napkin ring and it is cheaper to skim off the outside and inside surfaces of such an ingot in a lathe or boring mill than to plane off the surface defects of a rectangular slab. Other possible advantages were: more uniform and smaller grain size; the elimination of one rolling and annealing operation; and greater economy in rolling and shearing strip.

Approximately 30 tons of brass were centrifugally cast and rolled to finished strip. It was definitely established that a superior quality of rolled brass strip can be produced from an ingot cast centrifugally under properly controlled conditions.

The size of the ring was 2 ft. 2 in. by 15 in. by ⅝ in. To provide a suitable non-oxidizing atmosphere during the pouring operation, a coal gas atmosphere was provided in the spinning mold. This necessitated a notable innovation in the design of centrifugal casting machines; the whole of the supply of molten brass is transported into the spinner at once instead of allowing it to travel into the spinner from an outside container by means of a launder.

A technique was finally evolved which resulted in the ability to cast rings of excellent quality every time, weighing about 500 lb. each and capable of being machined for rolling with very little overall loss. After machining, the rings were sawed through in two places at opposite ends of a diameter by means of a band saw. A few castings were opened out in one piece and rolled as such.

The available customers' reports on the rolled brass are promising. The rejections for surface flaws by one manufacturer decreased from 45 to 6%. Another customer, who makes very deep pressings, pays extra for spun cast metal. A third has found that the centrifugally cast metal in the cheaper 63:37 grade will deep draw equally well as the more expensive 66:34.

The present indications are that, despite the extra cost incurred by machining, the savings and advantages in other directions coupled with a slightly increased price from certain customers might ultimately lead to a regular routine production from a battery of machines fed from a single large electric melting unit. (T. B. Cros. *Metallurgia,* Vol. 35, Jan. 1947, pp. 141-146.)

Flame Spraying of Powdered Materials

Condensed from "Sheet Metal Industries"

For a long time wide use of powder in metal spraying pistols was restricted because most metal powders in being blown through a length of tubing tend to be self-clogging. This difficulty has been overcome by sucking powdered materials through tubes and orifices where it would be impossible to blow them.

A variety of gases can be used, but the most popular is oxygen with acetylene, propane or an enriched coal gas. The temperatures reached by the powder are controlled by varying the air pressure with the highest pressures used for very low melting point materials. With plastics most of the powder is fused in passing through the flame. In the case of metal powder, however, it is fairly certain that the particles are not molten when they hit the surface to be sprayed. Almost any metal with a melting point under 2910 F can be sprayed satisfactorily.

Sprayed zinc coatings have been used on all types of articles. Spraying has the advantage that all shapes and sizes can be coated with a very thick coating. In recent months much attention has been given to the use of zinc spraying on steelwork, particularly as an undercoat for paint. With the rising cost of painting, it is more than probable that zinc spraying will soon be applied to all structural steelwork. Interesting results have been observed with the use of selected zinc alloys and with the admixture of aluminum or plastic powder with the zinc.

There have been a number of developments in the application of aluminum for improving the heat resistance of steel. Duraluminum constructional members have been sprayed to give improved corrosion resistance and a good basis for paint.

Almost all nonmetallic substances with a melting point under 750 F can be successfully put through the flame pistol. Powder spraying of plastics may considerably exceed that of metals. Bitumen was one of the earliest nonmetallic materials sprayed. Synthetic Thiokol rubber has received considerable development. During the war the main use of Thiokol sprayed coatings in Britain was in connection with marine work. Shellac, which is particularly easy to apply, has been used on electrical switchgear parts.

A number of well-known plastic materials are quite adaptable to flame spraying. Excellent results have been achieved with polythene, which has great potentialities in the chemical, food, electrical and radio industries. While flame sprayed finishes will not seriously displace synthetic finishes applied by brushing, dipping or air spraying, flame spraying does eliminate many of the difficulties encountered in these processes by dispensing with solvents. (W. D. Jones. *Sheet Metal Inds.,* Vol. 24, Feb. 1947, pp. 375-382.)

DIGEST

Stability of Steels at Elevated Temperatures

Condensed from "Western Metals"

An investigation by the National Tube Co. is under way to study the stability of a large number of steels when exposed to elevated temperatures over various time periods up to 11 years. Thus, the objective of this program is to determine the grades or chemical compositions of steels which have greatest resistance to graphitization and retain favorable creep-rupture characteristics at elevated temperatures.

Sixty different steel grades involving structural conditions are included in the program. Approximately twenty others will be added in the near future. Creep-rupture properties will, in general, be determined instead of the usual creep properties because tubular products may fail under condition of creep-rupture, and the usual creep properties are considered to be of secondary importance.

Several interesting results can be reported from the 1000-hr. cycle tests completed. Open-hearth carbon steel deoxidized with aluminum, with silicon plus 1.4 lb. aluminum, or with titanium plus aluminum, showed considerable graphite after exposure at 1050 F and 1200 F. Of these steels, only those deoxidized with silicon plus 1.4 lb. aluminum showed no graphite at any of the three temperatures, and it is questionable if the same grade deoxidized with silicon plus 0.4 lb. of aluminum showed graphite at 1050 F.

In contrast to these results, deoxidized 0.12 to 0.18% carbon Bessemer steel, commonly substituted in service for 0.20 to 0.30% carbon open-hearth steel, showed no evidence of graphite at any of the three temperatures after exposures for 1000 hr. Capped low-carbon open-hearth and capped low-carbon Bessemer steel (not deoxidized) did not show any evidence of graphite at any of the three exposure temperatures after 1000 hr. None of the carbon-0.50% molybdenum steels (high or low aluminum deoxidation) have shown evidence of graphite after 1000-hr. exposure. (A. B. Wilder & J. D. Tyson. *Western Metals,* Vol. 5, Jan. 1947, pp. 13, 57.)

Corrosion Characteristics of Magnesium

Condensed from "Metal Industry"

In the past many manufacturers have hesitated to use magnesium and its alloys because of a widespread feeling that they would have poor corrosion resistance. This feeling has been due largely to: (1) the prominence given to corrosion tests in salt water; (2) the fact that the earlier commercial magnesium alloys contained comparatively large amounts of corrosion-stimulating impurities such as iron; and (3) the fact that magnesium is a comparatively active metal.

In order to investigate the corrosion characteristics of magnesium, accelerated corrosion tests were made under conditions simulating inland indoor conditions, inland outdoor conditions and marine atmospheric conditions. The alloys tested were: pure magnesium; M-1 (with about 1.6% manganese and under 0.018% iron); AZ61X (with about 7 aluminum, 0.4 manganese, 0.8 zinc and under 0.003% iron); and AZ31X (with about 2.8 aluminum, 0.5 manganese, 1 zinc and under 0.001% iron).

The results indicate that all the bare metals tested will withstand satisfactorily inland indoor atmospheric conditions where the air is uncontaminated as well as inland outdoor atmospheric conditions where the metals are exposed to uncontaminated air, are wet by rain and are dried soon after each wetting. The bare metals however, cannot be recommended to withstand marine atmospheric conditions where they are exposed to the action of salt water spray. It is interesting to note that ordinary bare steel also deteriorates rapidly under such conditions.

It should be stated that pure magnesium, AZ61X and AZ31X, have been found to withstand the action of salt solution when they are properly coated with special paint. So far, under these conditions, the painted M-1 alloy has proved to be less satisfactory than the painted AZ61X and AZ31X alloys. (R. R. Rogers, D. A. Tetu & H. Livingstone. *Metal Industry,* Vol. 70, Jan. 3, 1947, pp. 9-10.)

Magnesium Alloys in Aircraft Construction

Condensed from "Revue de l'Aluminium"

The use of magnesium alloys in aircraft construction increased tremendously during the war. Their major applications have been in the form of castings, generally of magnesium-aluminum-zinc-manganese alloys. The aluminum and zinc increase the strength and hardness while the manganese serves to improve the corrosion resistance. The alloys with 7 to 11% aluminum (or 7 to 13% aluminum plus zinc with 5% minimum aluminum) may be improved by a long homogenization near to 790 F, followed by air cooling and, if desired, precipitation treatments.

Magnesium alloys have a low modulus of elasticity which indicates a considerable capacity for absorbing elastic strains. They likewise have excellent resistance to fatigue. For this reason, magnesium alloys are ideal for parts of landing gears. In engines they are used for parts such as cylinder head covers, diffusers, and oil pump bodies. For these applications, the castings must be designed and made with the greatest care. The most serious structural defect, and the most difficult to detect, is microporosity.

Wrought magnesium alloys have characteristics which should be very interesting to aircraft designers, but they are not used to the extent that they might be. Magnesium alloy sheet is used for body sheathing and oil and gasoline tanks. The corrosion of tanks containing gasoline with ethyl lead additions has been overcome by the use of a cartridge containing a mixture of fluoride inhibitors.

Wrought magnesium alloys have not been used more in France because of the lack of suitable fabrication equipment. For example, France does not have the powerful hydraulic presses needed for forging large parts of high strength magnesium alloys. (J. Gris. *Revue de l'Aluminium,* Vol. 23, Nov. 1946, pp. 355-362.)

The X-Ray Photometer for Nondestructive Testing

Condensed from "General Electric Review"

X-ray photometry is a new branch of nondestructive testing utilizing a combination of X-rays and phototubes for measuring X-ray absorption of materials. The method uses a divided X-ray beam; half the beam is passed through a standard absorber and the other half through the test specimen. The two beams then impinge upon a fluorescent screen; the light created by fluorescence is picked up by a phototube, and amplified. A calibrated wedge-type variable attenuator disk rotates in the beam which passes through the test specimen in such a fashion as to insert a known absorption, depending upon the angular position of the disk. Thus, the position of the disk gives a direct indication of the difference in absorption of the two samples.

Many applications are possible for an instrument of this nature. It opens a band above the ultraviolet spectrum and in the lower end of the X-ray spectrum to industrial inspection and test methods. It can reach up into the normal radiographic range and find applications such as control of thickness of hot rolled steel. It has wide application in quantitative chemical analysis.

It is particularly desirable in those measurements where the controlling component is of considerably higher atomic number than that of the other constituents of the product being measured. It has the unique advantage that the absorption of X-rays is independent of the physical state of the matter being traversed. The material to be tested is not harmed in any way since there is no physical contact.

To illustrate the applications of X-ray photometry, here are a few possible uses: the copper content of aluminum sheets can be checked; lead glass can be distinguished from soda glass, or the percentage of lead in glass determined; the thickness of silver deposit on glass mirrors may be checked; and the thickness of silver emulsion on film may be checked. (C. D. Moriarty. *Gen. Elec. Review,* Vol. 50, Feb. 1947, pp. 39-42; T. C. Michel & T. A. Rich, *Ibid,* pp. 45-48.)

A German Plastic Made from Powdered Polystyrene

Condensed from a Report from the Office of Technical Services

In Germany during the war a tough plastic film with excellent dielectric and mechanical properties was made by means of a conversion process on powdered polystyrene. The film, called "styroflex," was used as an insulating material for high-frequency coaxial cables and as a substitute for mica sheets in high-precision fixed capacitors.

This polystyrene film was made in thicknesses from about 0.0004 to 0.0006 in. and in widths from about 0.04 to 10.0 in. The film has a tensile strength of 10,000 psi. and a compressive strength of about 13,500 psi. Its dielectric constant is 2.5, and its breakdown voltage, 100,000 v. per 0.04-in. thickness. The film is resistant to water, acids, alkalies, alcohols, and mineral, animal and vegetable oils.

The raw material, polystyrol, was manufactured by a continuous polymerization process. It contained no iron and its impurities totaled no more than 0.1%. In converting it into a film no plasticizer, lubricant, anti-oxident, or stabilizer was used. The conversion was accomplished by mechanical processes.

The conversion machinery consists of a disk grinder, an extruder, a spreader, a trimmer, and take-up mechanism. The grinder breaks the polystyrol into particles of 20 to 30-mesh. The extruder heats the powdered polystyrol into a plastic mass and then forces it through a fine screen and die. The spreader stretches the extruded plastic into a film. The trimmer then shaves the edges of the film and the take-up mechanism rolls the film into spools. (Walter A. Klein & John A. Lunn. Report, *Office Tech. Services,* 32 pp.)

A Rapid Method for the Analysis of Light Alloys

Condensed from "Journal of the Institute of Metals"

Spectrographic analysis of light alloys is not sufficiently accurate to justify its extended use in estimating the alloy content of DTD 300 (aluminum alloy with about 10% magnesium) and DTD 59A (magnesium alloy with about 8% aluminum). Preliminary work on analysis of light alloys based on changes in electrical resistivity showed that the resistivity was about 15 times as sensitive to composition changes as was the density. With careful control, there is a straight-line relationship between the magnesium in DTD 300 and the aluminum in DTD 59A and the resistivity.

In DTD 300, a change of resistivity of 0.53 microhm-cm per 1% magnesium was obtained with a standard deviation of 0.16% magnesium. For DTD 59A, a slope of 0.75 microhm-cm was obtained with a standard deviation of 0.13% aluminum. The results obtained depended on porosity, microstructure and casting procedure, so all these factors must be standardized.

This method of analysis is applicable for the estimation of magnesium in aluminum alloys with 9 to 11% magnesium where the alloys are made from 99.7% aluminum and commercially pure magnesium or scrap of similar derivation. It is also suitable for aluminum in magnesium alloys with 7 to 9% aluminum, 0.5% zinc and 0.2% manganese where the purity corresponds to that of virgin ingot material. With these alloys, however, it may be necessary to re-establish the correlation for each batch of raw material if the zinc and manganese contents differ appreciably.

The work completed thus far shows that electrical resistivity measurements offer an extremely rapid method of foundry analysis with the added advantages of simple equipment and a high degree of accuracy. (L. Rotherham & J. I. Morley. *J. Inst. Metals,* Vol. 13, Dec. 1946, pp. 213-222.)

Some Metallurgical Factors Which Affect Machinability

Condensed from "Metal Treatment"

Difficulty is often experienced in machining different heats of steel which, from ordinary metallurgical considerations, should give no trouble when cut under commercial conditions. Generally speaking, these cases are confined to alloy steels machined in the heat treated condition at a tensile strength of 100,800 to 156,800 psi.

After considerable experimental work a heat treatment was evolved which improves the machinability without materially affecting the mechanical properties of the steel. This treatment consists of double tempering and oil quenching hardened steel, the second tempering temperature being approximately 45 F lower than the first. Water hardened steels do not respond to the same extent as do the oil hardened types.

The higher alloy steels appear to give a greater improvement in machinability by this treatment than do the lightly alloyed and carbon grades. This improvement is most noticeable under heavy duty machining conditions. The improvement in machinability is probably due to a combination of the following: slight softening, more favorable microstructure, resolution and minimizing of micro and macro internal strains, decrease in strain hardenability, decrease in the friction of the chip passing over the tool, and decrease in the internal friction of the steel during chip formation.

Another problem often encountered in gear shaping practice is poor surface finish. Oil hardening and double tempering does not cause any improvement in the surface finish. However, good results were obtained by "nicking" the disk type cutter and by coarsening the austenitic grain size, followed by normalizing and subsequent annealing if air hardening had taken place. The latter method appeared to be more effective. (K. J. B. Wolfe. *Metal Treatment,* Vol. 13, Winter, 1946-47, pp. 225-247.)

Ceramic Coatings for High Temperature Applications

Condensed from a Paper of the National Advisory Committee for Aeronautics

An investigation was undertaken to develop ceramic coatings that will prolong the life of alloys used in turbines, especially the blades, or permit their use at higher temperatures than would otherwise be practical.

These studies have so far indicated clearly that some ceramic coatings yield a high degree of protection for high-temperature alloys in a strongly corrosive atmosphere at elevated temperatures.

It was found that some of the coatings will withstand 500 hr. in air at 1500 F with little visible change, while serving to eliminate or greatly reduce the oxidation that occurred on uncoated alloys, which received the same treatment. The high-temperature load tests indicated that, at loads sufficiently low to permit a life of the alloy beyond 600 hr., some of the coatings had a significantly beneficial effect. It was also found that some of the coatings permitted alloys S-816 and S-590 to retain approximately their initial 0.2% offset yield value under conditions that almost completely corroded the uncoated alloys, namely, heating in an H_2S atmosphere at 1350 F for prolonged periods.

The microscopic examination of treated specimens indicated the importance of working toward the elimination of pores or other discontinuities in the coatings, some of which are connected with the evolution of gas at the surface of the alloys, while the coatings are being fired. Indications thus far obtained give promise of substantial further progress in the development of protective ceramic coatings. (W. N. Harrison, D. G. Moore & J. C. Richmond. *Nat. Advisory Committee for Aeronautics,* Tech. Paper No. 1186, 28 pp.)

German Production of Spun Pipe

Condensed from "Foundry Trade Journal"

The bulk of German pipe was produced at Gelsenkirchen, Wetzlar and Brebach-Saar. The first two employed the normal Delavaud process and the latter used the sandspun process. In general, no outstanding improvements since the plants were last visited in 1938 were encountered. There were no indications that the processes were more efficient than those used in Great Britain.

Fairly long runs of about 20 hr. were

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. . . with only a trifle less linear shrinkage than other aluminum alloys, no change in the pattern scale for running No. 12 Alloy is needed.

. . . checking is rarely encountered.

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DIGEST

normal; the cupola lining life was six shi or about 600 tons of iron. The lining then stripped back to the brick face a replaced by pneumatic ramming. The ca ing machines were of normal design. Gelsenkirchen, the molds, after use, we reduced to a smaller size by a cold "forgin operation under heavy hydraulic pressu the method being similar to that in u at the Burlington plant, U.S.A. The proc was not considered entirely satisfactory.

At Wetzlar, flanged pipes were produc by the spun process for high pressure a plications. Another development was t centrifugal casting in dies of pipe flang for screwing to double spigot pipes pr duced from scrap socket pipes.

In connection with dipping, the opinio was expressed by H. Schlumberger th taste will always occur if naphthalene present. Every endeavor should be made eliminate this from the mixture. The recom mended mixture is 65% pitch and 35 oils. Pipes should never exceed 390 F whe entering the dip, the temperature of whic should be carefully maintained at 250 They should not be artificially cooled as un stable coating will result if the cooling too rapid. (M. M. Hallett. *Foundry Trad J.*, Vol. 81, Feb. 6, 1947, pp. 136-138.)

New Steels and Their Uses

Condensed from a Paper of the Society for Advancement of Management

The immense amount of research work on the broad range of carbon, alloy and stainless steels, and on the perfection of metallic and nonmetallic coatings of many kinds has made steel versatile to a degree hardly imagined even ten years ago.

One of the significant developments of the war was the recognition of the importance of hardenability. This has led to a demand for steels (known as "H" steels) in which the hardenability is restricted to a specified range.

Another development was the use of boron in very minute percentages to increase hardenability. A multi-purpose steel, Stainless W, combining the high strength and corrosion resistance of standard 18:8 stainless with hardenability obtained through heat treatment, was announced over a year ago. Another new steel is a carbon-molybdenum-chromium composition designed to meet requirements of increasingly high temperatures in the steam lines of power plants and chemical industries. This steel suffers no appreciable loss of creep strength when used at temperatures up to 1100 F.

Another new material, developed during the war, is electro-galvanized steel. This is excellent for applications where a light galvanized coating is practicable and where good paint finish is wanted.

Enameled sheet is receiving increased use in applications for liners for hot water heaters, refrigerators, washing machines, and the like. The prospects are good that single coat white enamels may become available not too far in the future. If and when suitable frits are developed, the steel industry will be prepared to furnish suitable steels.

Galvanized sheet and strip is also receiving increased attention. Depending upon the particular sequence of bonderizing, galvanizing, and cold rolling, the fabricator may obtain a bright or dull finish, have superior ductility suitable for deep drawing jobs, and have a surface excellent for paint adherence. The product can be used for such applications as car roofing, barrel and drum stock, and heating, ventilating and air conditioning equipment. (Milton Male. Paper, *Soc. Advancement Management*, Feb. 20, 1947 Meeting, 10 pp.)

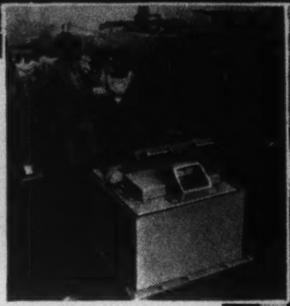
New Type Gray Cast Iron

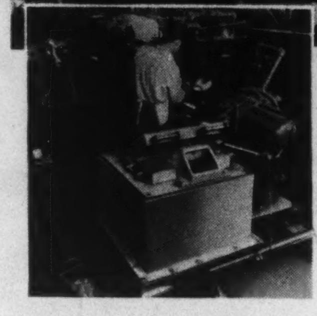
Condensed from "Metallurgia"

Iron, as cast, is being successfully produced by a process, the details of which have not yet been disclosed, with a nodular graphite instead of the elongated flake graphite generally found in gray cast iron. The graphite in the new type iron resembles the temper carbon found in annealed malleable cast iron.

In a heat of hematite pig iron with 3.9 carbon and 2.6% silicon, a standard 0.875-in. test bar gave in the untreated and treated states, respectively, tensile strengths of 34,720 and 59,360 psi., transverse strengths of 65,855 and 107,295 psi., shock resistances of 13 and 47 ft.-lb. and Brinell hardnesses of 185 and 215. The new type iron has a small measureable elongation, 1 to 2% with the higher carbon contents and 2 to 3% with the lower carbon contents. Another feature of the treated material is the uniformity in properties from piece to piece.

The most significant feature of this new development is that it is applicable, and indeed most readily applicable, to the





AJAX
TAMA-WYATT
IS MAKING NEWS BY ELECTRIFYING THE ALUMINUM ALLOY INDUSTRY

Views showing AJAX furnaces in operation at the Johnson Motors Division of the Outboard Marine & Manufacturing Co., Waukegan, Ill.

ACCURATE CONTROL FOR MASS PRODUCTION OF PRECISION PARTS IN AJAX ELECTRIC MELTING FURNACES

Photos Courtesy "Electrified Industry"

A large number of aluminum die castings are used in the manufacture of outboard motors. The more precisely these castings meet standard specifications for size, strength, quality and weight, the lower are overall production costs. AJAX Tama-Wyatt Induction Melting Furnaces contribute to the uniformly high efficiency of the Johnson plant and to the quality of their castings.

THE aluminum foundry has long needed an induction furnace suited to continuous high output. AJAX Tama-Wyatt Induction Melting Furnaces are being extensively installed by nationally known manufacturers like the Johnson Motors Division of the Outboard Marine & Manufacturing Co., in their new all-electric die casting plant at Waukegan, Ill., U.S.A.

For the first time time in industrial history this die casting plant is using electric furnaces exclusively to melt and hold metal to be processed in die casting machines.

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Trenton 7, New Jersey

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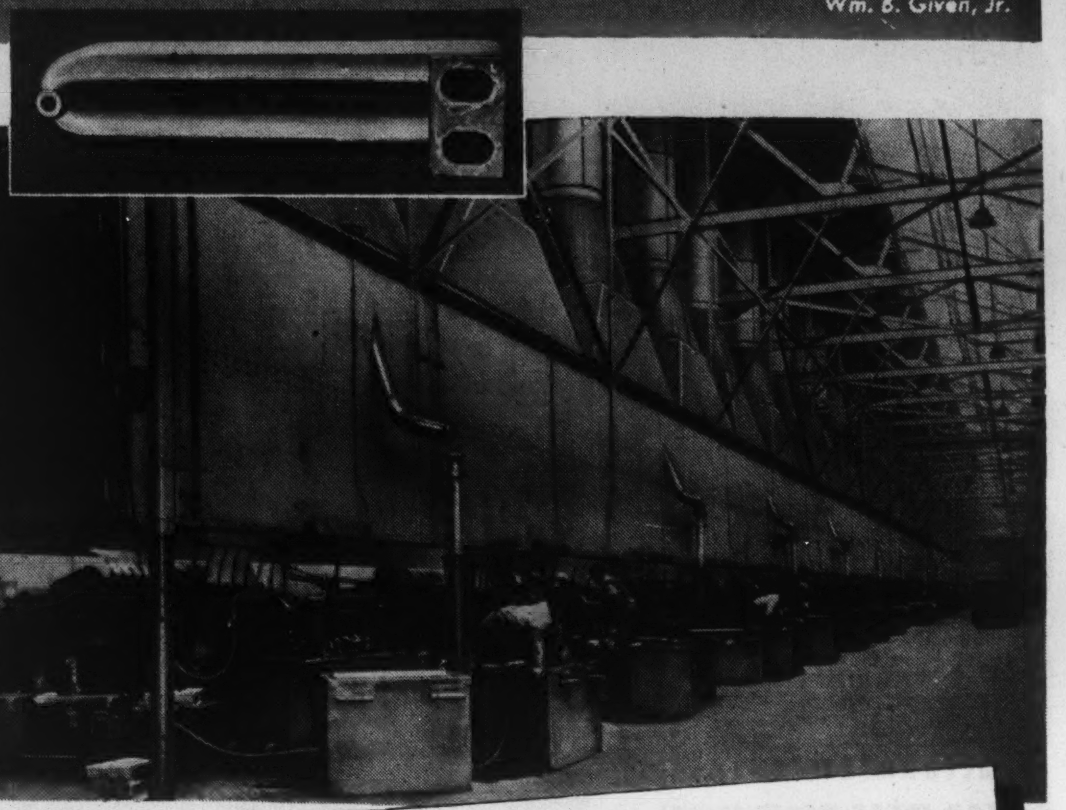

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When Kemp immersion melting equipment was decided upon for one of the world's longest lines of tin-stacks, the choice of heating element was carefully made. The tin plating of steel demanded the travel of flue gas through a complete tubular loop below the surface of the metal bath. Determining the best metal for this loop called for full consideration of strength and pressure tightness as well as resistance to thermal shock due to intermittent heating.

The answer: structurally sound non-porous castings of heat-resisting Meehanite, free from all foundry defects and suitable for immersion in dense liquids. The practical benefits: a method was made possible that surpassed external-firing practice by consuming less gas, controlling temperatures more closely, reducing dross formation drastically and increasing production rate.

As in this case of The C. M. Kemp Mfg. Co. of Baltimore, Md., you can get a type of Meehanite which closely fits a specific set of job requirements in its metallurgical content and combination of performance characteristics. Meehanite castings as made by Brake Shoe give you the further assurance of an unequalled foundry background.

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DIGEST

medium and high carbon and silicon irons, that is to the irons most easily castable and machinable and least subject to shrinkage in castings. The new iron will not supplant high strength irons but supplement them.

This process will not only put ordinary castings into a new class mechanically and provide a new basis for the development of high strength and special cast irons, but it will involve a new approach to the design of iron castings. The process can be used satisfactorily on cupola melted irons, but much work has to be done before it can be applied in industry. (*Metallurgia*, Vol. 35, Dec. 1946, pp. 71-72.)

Supermalloy—A New Magnetic Material

Condensed from the "Journal of Applied Physics"

A new magnetic alloy that has an initial permeability several times as high as that of molybdenum permalloy and mumetal alloys now in general use has been developed. It has already been made in considerable quantities for use in apparatus supplied to the U. S. Navy.

The composition of the alloy is about 79 nickel, 5 molybdenum, 15 iron, and 0.5% manganese. Impurities such as silicon, carbon, sulfur, etc., are lower than in most commercial alloys. Materials are melted in vacuum in an induction furnace of about 30-lb. capacity, and poured in helium or nitrogen at atmospheric pressure.

Ingots are hot and cold rolled by commercial methods to any thickness down to 0.00025 in. The tape is wound spirally to form toroidal specimens. When insulation is desired, a thin film of magnesia is applied in carbon tetrachloride suspension so that a film about 0.00005 in. in thickness is left on each side of the tape. Transformer cores are made in this manner. Heat treatment consists of maintaining at 2370 F in pure dry hydrogen, and cooling through the temperature range 1120 to 575 F at a critical rate appropriate to the composition.

The use of supermalloy in communication transformers permits a threefold increase in the range of frequencies transmitted, and a pulse duration three times that heretofore obtained. Its high permeability opens the way toward further improvements in transformers operating at frequencies common in communication engineering. (O. L. Boothry & R. M. Bozorth. *J. Applied Physics*, Vol. 18, Feb. 1947, pp. 173-176.)

BOOK REVIEWS

Order

he Science of Plastics

HE CHEMISTRY OF COMMERCIAL PLASICS. *By R. L. Wakeman. Published by einhold Publishing Corp., New York, 947. Cloth, 6¼ x 9¼ in., 836 pages. rice $10.00.* The author of this valuable nd comprehensive work has spent years f research and study in this field. He is esearch director of the Onyx Oil & hemical Co., Jersey City, N. J. He was Fellow, and is now an Advisory Fellow f the Mellon Institute, Pittsburgh.

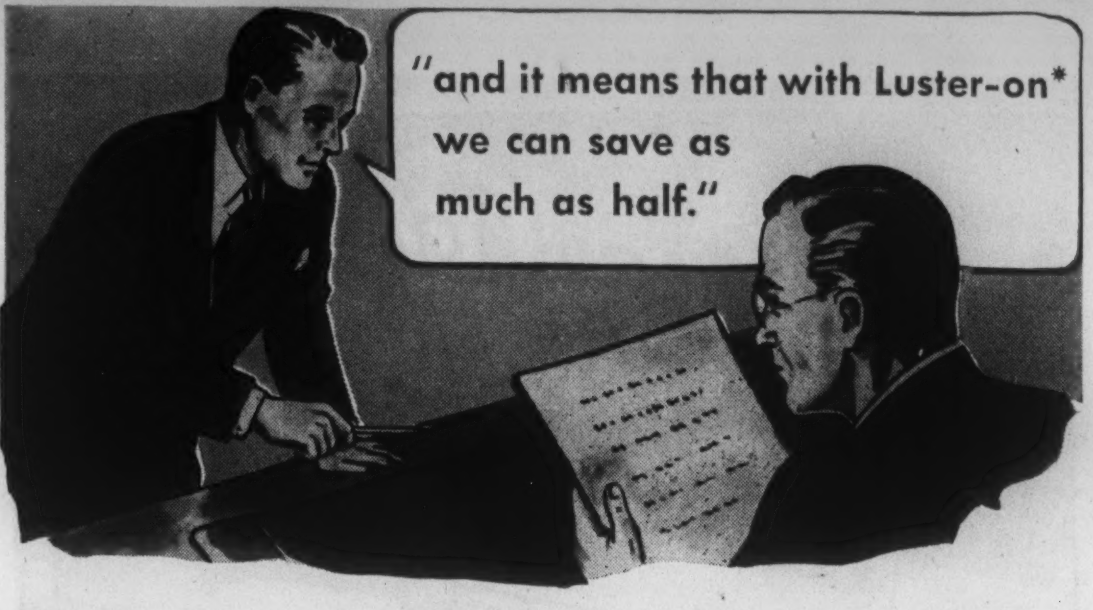
There has been a need for many years or a book which would correlate scientific nformation in the domain of high polyers with actual industrial practice. The uthor was convinced of this when he tarted to conduct research in this field. nd this, he says, became still more aparent when he was later engaged in niversity instruction. "The industrialist eeking to apply plastics in his business ished an introduction to the laboratory." his is the main object of this treatise hich the author has successfully attained.

The book is described as the most comrehensive, detailed and informative volme on plastics published in recent years. ll the latest developments are most horoughly covered from phenolic and rea resins to the protein plastics and the ilicone compounds. The text attempts to e selective and not encyclopedic as reards information which is particularly ertinent to industrial practice. There is wealth of technical information which ill be welcomed by a large audience.

At the end of each chapter there is an bbreviated list of literature references hich are not claimed to be comprehenive. There is also an abundance of illusrations—324 halftones and drawings. pecial mention should be made of the arious indexes, which are very helpful. here are 26 chapters which cover most f the plastics, resins and allied products. The author has made an impressive ddition to the literature in this field.

Structural Materials Engineering

RESISTANCE OF MATERIALS — THIRD EDITION. *By Fred B. Seely. Published by John Wiley & Sons, Inc., New York, 1947. Cloth, 5¾ x 8½ in., 486 pages. Price $4.00.* In this new edition, treatment of the subject is devoted to engineering problems in general; emphasis on any particular field is avoided. An excellent


"and it means that with Luster-on* we can save as much as half."

"This Report," the Methods Engineer went on, "sets the facts down in black and white. With Cadmium so hard to get—"

"It says here," the Boss interrupted, "that Luster-on* on zinc gives a bright, attractive surface that resists stains, fingermarks and white corrosion."

"That's right," said the M. E. "But from my standpoint the biggest appeal is the cost angle. Luster-on* on zinc costs only about half as much as Cadmium."

"It means revising all your recommendations," the Boss reminded him.

"Exactly. But if plating zinc with Luster-on* makes our product as good—or better—than it's ever been, I'd say that's a better bet than fighting for Cadmium and paying more for it when we do get it."

"That's good sense," the Boss said. "Get all the dope on Luster-on* as soon as you can."

The Boss and his M. E. are talking about a Comprehensive Cost Analysis Report just prepared. In comparing the costs of Luster-on* on zinc with Cadmium, this data reveals some startling facts. A copy will be sent you free by simply filling out and mailing the coupon.

*Patent applied for.

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MATERIALS & METHODS MAY

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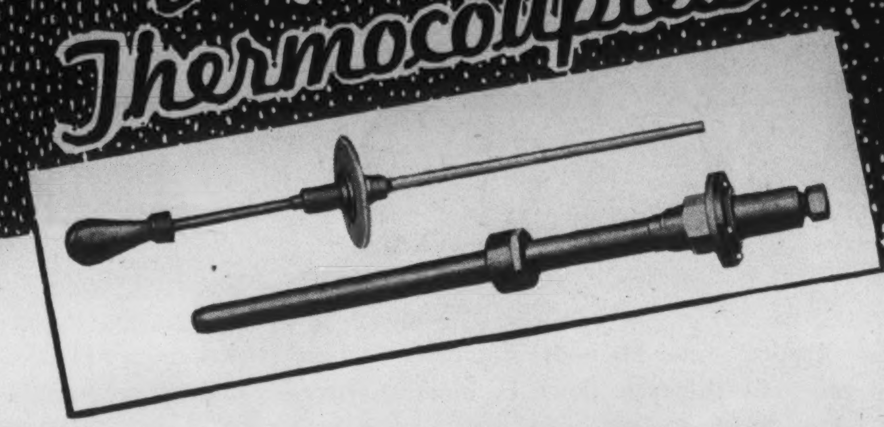


TO MULTIPLY
THE RANGE OF YOUR
PYROMETER INSTRUMENTS

ENGELHARD manufactures a complete range of assembled thermocouples consisting of thermo-elements with insulators, protection tubes, terminal heads, couplings and various accessories. Thermo-elements may be platinum vs. 90% platinum 10% Rhodium, Reclaiming Platinum vs. Platinum Rhodium, Chromel vs. Alumel, Iron vs. Constantan and Copper vs. Constantan.

Selection Is Important

ENGELHARD assembled Thermocouples insure maximum efficiency from their pyrometer instruments because each is made up from selected individual parts, chosen because of their ability to meet the requirements of a specific application.

Whether the atmosphere encountered is reducing, oxidizing or corrosive—the maximum temperatures likely to be encountered, probable quick changes in temperatures, how often the thermocouple will be removed or the lead wires disconnected—these are only a few of the main points in successful thermocouple selection.

Take your Thermocouple problems to Engelhard!

CHARLES ENGELHARD, INCORPORATED
90 CHESTNUT ST., NEWARK, NEW JERSEY

foundation is thus furnished for the mo advanced study of mechanical, civ aeronautical and other divisions of eng neering. It is pointed out that none the features which have made the bo popular and widely used for ready refe ence by practicing engineers have be lost in the revision. The main proble in this, as in other editions, consists determining the relationship between th loads acting on a member and the r sulting stresses and deformations in th member.

In the 12 years since the second editio the use of light metals has greatly e panded, as has also the application high-strength metals such as alloy steel Attention is devoted to the effect of the materials. Welded connections are als given attention.

Besides a complete resetting of th type, a large number of new problems an new figures have been added. In additio to minor changes, important modification include: A decrease in the use made o the double-integration method; more emphasis on the use of Mohr's circle; considerable change in the chapter o columns; and the addition of a brie chapter on the vibrational characteristic on load-resisting members.

The text is divided into two parts i which there are 20 chapters. There ar many illustrations, mostly drawings.

Adhesive Materials

THE TECHNOLOGY OF ADHESIVES. B *John Delmonte. Published by Reinhol Publishing Corp., New York, 1947. Cloth 6¼ x 9¼ in., 516 pages. Price $8.00* The author is technical director of the Plastics Industries Technical Institute and is well-known for his books and contributions to journals.

It has been the aim of the author in this book "to tie together as closely as possible developments in plastics with those in adhesives," for developments in the latter have closely paralleled those in high polymers. To do this has meant, he says in the foreword, giving considerable weight to the utilization of synthetic resins in adhesive formulations, in some instances disproportionate to the actual quantity used. He predicts that, with the growing interest in structural applications of plastics and the development of composite laminated structures of maximum efficiency, adhesives will assume a much more prominent position in the industrial picture.

All kinds of adhesive materials are discussed in this addition to the Reinhold Series of books on plastics. Both the chemistry and the industrial applications of adhesives are covered, particularly with reference to plywood manufacture where light weight and high strength are imperative.

There are 20 chapters, each one having a voluminous list of references. The text is illustrated.

The volume should have a wide appeal to those concerned with problems in the metal and wood fields.

Mechanics of Materials

ADVANCED MECHANICS OF MATERIALS. *By Glenn Murphy. Published by McGraw-Hill Book Co., Inc., New York, 1946. Cloth, 6¼ x 9¼ in., 307 pages. Price $4.00.* The author has written this book for an advanced undergraduate or graduate course in strength of materials.

Titles of the 11 chapters are as follows: Relationship of Materials to Design; Stresses and Strains at a Point; Stress-Strain Relationships; Theories of Failure; Axial Loading; Cylinders, Spheres, and Disks; Torsion; Flexure; Cross Shear; Introduction to Photoelastic Analysis; and Compressive Loads and Buckling. Emphasis is placed upon the tools—statics, geometry, and properties of the material—available for investigating new problems, and upon the way these tools are applied.

Each chapter concludes with a set of problems, answers to most of which are supplied. There are 309 such problems.

Resistance Welding

RESISTANCE WELDING MANUAL—REVISED EDITION. *Published by Resistance Welder Manufacturers' Assoc., Philadelphia, Pa., 1947. Cloth, 6 x 9 in., 552 pages. Price $3.00.* This is an unusually comprehensive text on all phases of resistance welding. Compared with the first edition, this revised edition is practically twice the size of the first, due to extensive revisions. Twenty entirely new chapters have been added, and the tables of recommended procedure have been revised to bring them up-to-date.

A new section contains chapters on quality control, standard tests and instrumentation. There is also a chapter on recommended maintenance practices for resistance welding machines, a glossary of approved definitions, and a collection of useful tables.

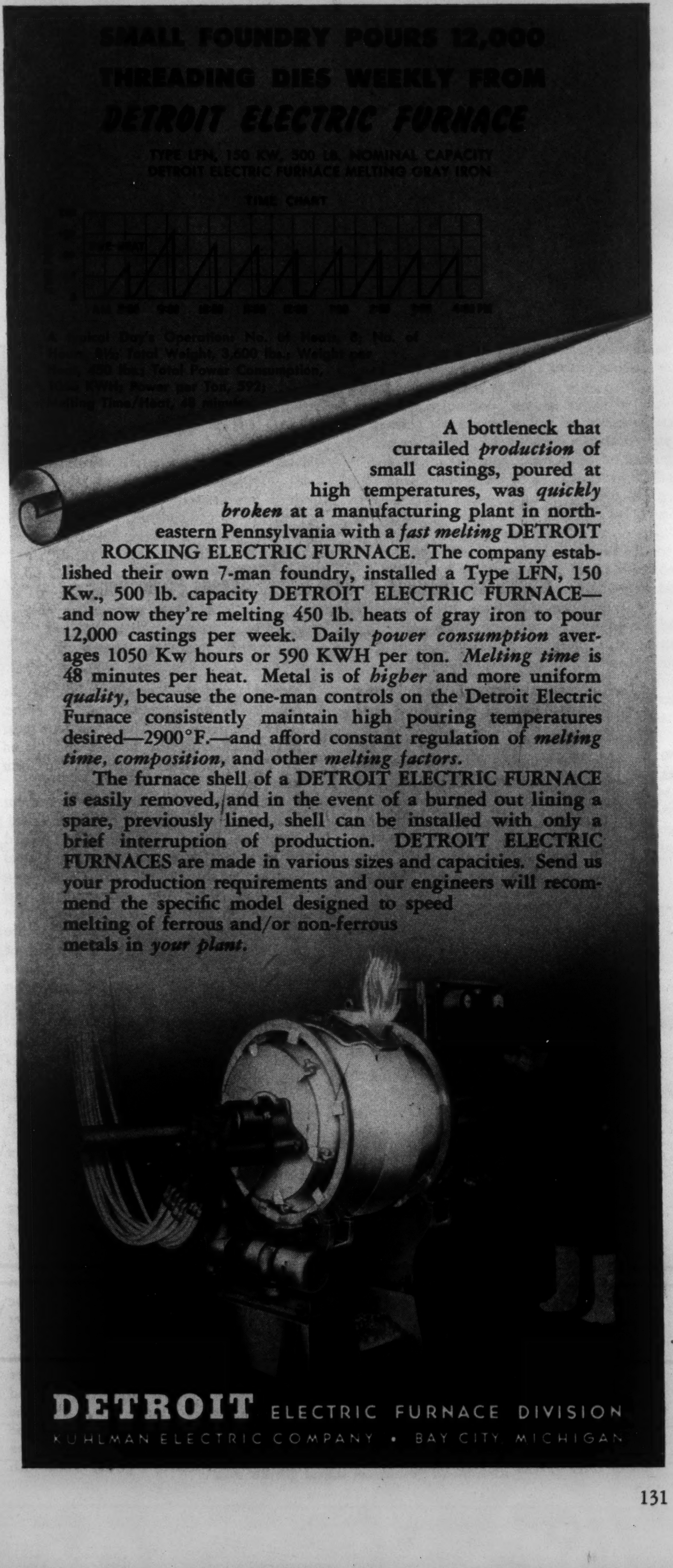
Other New Books

DICTIONARY OF MACHINE SHOP TERMS. *By A. C. Telford. Published by American Technical Society, Chicago, 1947. Cardboard, 3 x 5¼ in., 292 pages. Price 75c.* Contains all the necessary terms used in a machine shop, with a sprinkling of others commonly associated with such work.

A.S.T.M. SPECIFICATIONS FOR STEEL PIPING MATERIALS. *Published by American Society for Testing Materials, Philadelphia, Pa., 1946. Heavy paper, 6 x 9 in., 296 pages. Price $3.00; to members $2.25.* Includes specifications for various types of steel pipe ranging from ordinary carbon steel pipe for a variety of uses to high-alloyed steels for high temperature and high pressure service, including stainless steel, plus castings, forgings, bolting materials and nuts.

UNDERGROUND CORROSION (CIRCULAR C450). *By Kirk H. Logan. Published by National Bureau of Standards, 1945. Obtainable from Supt. of Documents, Government Printing Office, Washington 25, D. C. Price $1.25.* Results of the National Bureau of Standards investigations of underground corrosion.

SHOT PEENING. *Published by American Wheelabrator & Equipment Corp., Mishawaka, Indiana, 1946. Cardboard, 6 x 9 in., 128 pages. Price $1.50. (Free to interested executives.)* A complete and detailed explanation of the process of shot peening for the use of engineeers and production men.


SMALL FOUNDRY POURS 12,000 THREADING DIES WEEKLY FROM *DETROIT ELECTRIC FURNACE*

TYPE LFN, 150 KW, 500 LB. NOMINAL CAPACITY
DETROIT ELECTRIC FURNACE MELTING GRAY IRON

A Typical Day's Operation: No. of Heats, 8; No. of Hours, 8½; Total Weight, 3,600 lbs.; Weight per Heat, 450 lbs.; Total Power Consumption, [illegible] KWH; Power per Ton, 592; Melting Time/Heat, 48 minutes.

A bottleneck that curtailed *production* of small castings, poured at high temperatures, was *quickly broken* at a manufacturing plant in northeastern Pennsylvania with a *fast melting* DETROIT ROCKING ELECTRIC FURNACE. The company established their own 7-man foundry, installed a Type LFN, 150 Kw., 500 lb. capacity DETROIT ELECTRIC FURNACE—and now they're melting 450 lb. heats of gray iron to pour 12,000 castings per week. Daily *power consumption* averages 1050 Kw hours or 590 KWH per ton. *Melting time* is 48 minutes per heat. Metal is of *higher* and more uniform *quality,* because the one-man controls on the Detroit Electric Furnace consistently maintain high pouring temperatures desired—2900°F.—and afford constant regulation of *melting time, composition,* and other *melting factors.*

The furnace shell of a DETROIT ELECTRIC FURNACE is easily removed, and in the event of a burned out lining a spare, previously lined, shell can be installed with only a brief interruption of production. DETROIT ELECTRIC FURNACES are made in various sizes and capacities. Send us your production requirements and our engineers will recommend the specific model designed to speed melting of ferrous and/or non-ferrous metals in *your plant.*

DETROIT ELECTRIC FURNACE DIVISION
KUHLMAN ELECTRIC COMPANY • BAY CITY MICHIGAN

Engineering Shop Notes

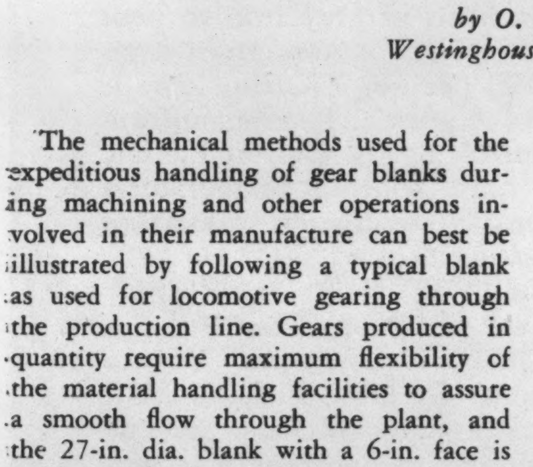
Mechanical Handling of Gear Blanks Speeds Production

by O. P. Adams,
Westinghouse Electric Corp.

The mechanical methods used for the expeditious handling of gear blanks during machining and other operations involved in their manufacture can best be illustrated by following a typical blank as used for locomotive gearing through the production line. Gears produced in quantity require maximum flexibility of the material handling facilities to assure a smooth flow through the plant, and the 27-in. dia. blank with a 6-in. face is typical work of this class.

Gear blanks of this size are made from a rolled steel section. Chucking blanks in the vertical lathes, preparatory to turning, facing and boring is facilitated by jib cranes with electric hoists. A chain sling with hooks passed through the holes in the web of the gear blank makes picking up and lowering a simple, yet safe operation.

The next manufacturing step is hobbing. The machined gear blanks are moved from the vertical lathes to the hobbers by an overhead traveling crane. After the teeth have been cut, the gear is removed from the hobber and placed in a nearby area preparatory to heat treating.



Quenching operations are expedited by an overhead trcvelling crane using a set of three special pick-up hooks.

Transfer to the heat treating department is accomplished with an overhead traveling crane. Four to six gears are carried on each trip by simply inserting a steel shaft or bar through the hubs and looping the chain sling over each end of this shaft. The gears are placed adjacent to the heat-treating furnaces, where they are picked up one at a time by a triad of special hooks slung from an electric hoist on a jib crane and placed horizontally on the furnace guide rails. When the gear is ready for quenching, an overhead traveling crane with a set of hooks like those used for furnace loading operations picks it up and carries it to the quench tank.

Plant layout necessitates transferring the gears to an adjoining production aisle for the finish grinding operation. The overhead traveling crane carries four to six gears simultaneously to the transfer car. Once on this car, a power truck pushes them to the next aisle, where they are again picked up en mass by an overhead traveling crane and deposited near a battery of grinding machines.

A jib crane with a hand operated chain hoist and a single hook that holds the gear in a vertical position is used to set up the bore grinder. Following this operation, the gear is moved to the cleaning and greasing area. From here they are loaded onto another transfer car and moved to the shipping floor. A jib crane with electric hoist lifts the gear from the floor and lowers it into a crate. When the crate has been sealed, a power truck with a forked elevator platform picks up th crated gear and transfers it to a car c truck for shipment.

As the size of the gear changes, vari tions in the procedures described ar employed, but regardless, the methods fo handling are basic if a smooth and effi cient flow of material through the plan is to result.

A Simple Quick-Acting Drill Jig

by Robert Mawson

Any machine shop which has had th experience of drilling holes in drop forged steel parts will know the trouble ofte experienced in locating them in the jig Often the surfaces, which are supposed to be flat, come warped, especially if th part is designed with a flange or web Drop forged steel plates with a centra strengthening web are typical. With such construction the metal tends to taper from the web to the outer edges in both directions. Following is a description of a specially designed jig for drilling six 7/32-in. holes in such a drop forged plate.

The drill jig designed for this operation is somewhat unusual as regards the locating and holding method. The tool is made with a cast iron base "A" with vertica walls on three sides, the casting being machined at the bottom and on the top On these upper surfaces is attached, b means of screws and dowels, a machin steel plate "B" in which is located, i their proper positions, the six tool stee drill guide bushings.

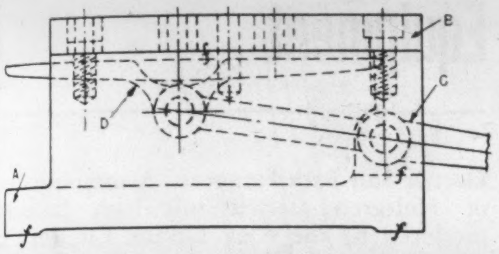
(Continued on page 133)

Near the right end of the jig base is placed a lever "C"; the shaft carrying this lever passes through the two vertical walls and a collar at the outer ends of the shaft holds it in position.

The right hand vertical wall is slotted for a depth sufficient for the movement of the lever. The extreme outer end of the lever is made as a weight to counteract the pressure of the drill when machining the holes.

At the inner end of the lever is a forked locating member "D," which straddles the web of the forging. This locating member can swing freely on its pin. The space between the two side walls is made slightly wider than the forging so that it can be slid into the jig easily.

To use the jig the operator lowers the locating member by raising the lever "C" and its weight. He then slides the forging into the jig until the piece comes against the rear wall finished pad. He next draws down the lever and this brings the locating member in contact with the under side of the forging.



Drawing of the drill jig for drop forged steel plates.

Since the member can swing on its pin, the member adjusts itself to any distortion of the forging. This motion also tends to push the piece back into the jig to the finished surface. Additional downward movement of the lever and weight will cause the locating member to force the forging into place on the under surface of the jig plate. The six holes can now be machined, the drill being guided through the bushings in the conventional manner.

The weight is then raised which removes the pressure from the forging, and the machined forging can be removed from the jig. It will be noticed that the forward end of the jig base has been shortened; also, there is no vertical wall at this end so the forging can be placed in or removed from the jig easily and quickly.

A stud that has broken off close to the surface can be easily removed by building up the end about 1/2 in. with steel welding rod so that it can be turned out with a pipe wrench when cool. The expansion caused by the heat of welding helps to free the stud since it tends to compress and crack rust formations on the threads. This method has been used successfully on studs from 1/4 in. to 1 1/2 in. in dia.

—From "Linde Tips"

A decent looking weld on galvanized material is difficult to make. The zinc not only volatilizes and creates a gas which is apt to cause the operator to be sick, but it tends to disrupt the arc in the sense that the appearance of the weld will not be satisfactory. To reduce this trouble, it is advantageous to drag an extremely short arc quickly across the joint, then brush vigorously with a wire brush to remove most of the galvanize in the joint area. —From "Welding Arcs"

Three-Dimensional Layout and Inspection of Castings

by Clifford A. Falkenan,
General Electric Co.

Inspection and layout of castings by a three-dimensional method of projecting accurate layout drawings upon a rough casting has been developed by engineers at the Pittsfield Works of the General Electric Co.

Originally designed to inspect and lay out parts for subsequent machining, this method has also been used for a rapid inspection of finished parts. Projection may also be employed during an actual machining process, whether the part to be machined is stationary or revolving. The equipment assures layout within fifteen thousandths of an in.

The installed apparatus consists of a layout image projector containing a photographic glass slide of the finished casting layout. The layout is projected by a lens directly upon the surface of the casting. To establish the plane of true projection and correct dimensions, a second projector—the inspection plane projector or light wand—over the inspection position is used. The light wand emits a sheet of light which falls vertically upon the casting.

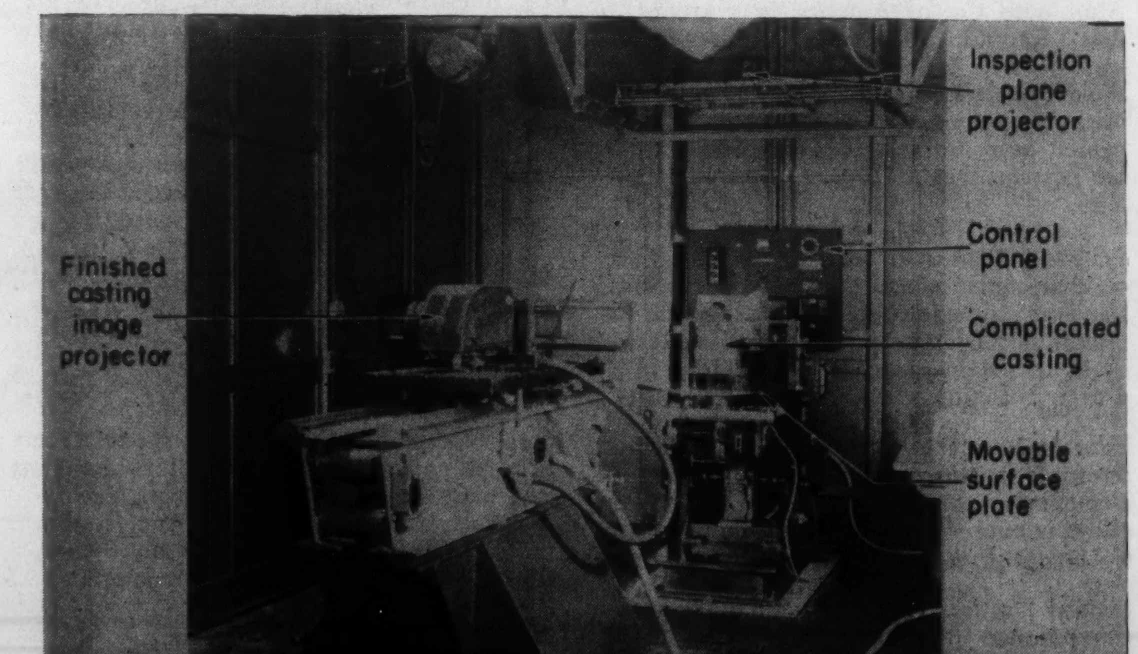
Both projectors operate in unison through a selsyn system. Thus, the light wand always designates the proper plane for the main projector's image as well as its correct focus and size.

The inspection pedestal assists in positioning the rough casting by means of an electric drive. An adjustable surface plate allows for the final location of the casting coincidental to the sheet of light from the inspection plane projector. Automatically, the finished layout will be projected properly on the rough casting.

When machining a piece which revolves and is symmetrical about the axis of rotation, the finished outline may be projected to serve as a template.

This template-projection system can be used in fabricating duplicate metal parts for tanks, boilers, and other burned-out and welded pieces. Variations of this system can be used for laying out intricate pieces, locating parts to be welded, shearing, and general layout operations.

To make this three-dimensional method practical, drawings of finished castings, which are suitable for photographing, are prepared. The size and focus of the drawing image on the ground glass of the camera are checked by microscope for accuracy.



Typical set-up for projection inspection of castings. This projection method can also be used during actual machining operations.

MANUFACTURERS'

Materials

Nickel Alloy Wire, Rod and Strip. Comparison of properties of Monel, nickel and Inconel and their alloys with other metals in wire, rod and strip form, and their many applications, are included in this 26-page, illustrated bulletin, No. D-2, issued by Alloy Metal Wire Co., Inc. (1)

Magnesium Alloys. Complete data on the resistance of magnesium alloys to corrosion, helium arc welding magnesium alloys, and magnesium ingots are presented by the Aluminum Co. of America in a group of data sheets consisting of 22 pages. (2)

Welded Stainless Tubing. Detailed specifications, properties, applications, etc., of Carpenter Steel Co.'s welded stainless tubing are presented in a 16-page, illustrated bulletin. (3)

Synthetic Resin Solutions. A detailed chart of characteristics and formulae of various standard synthetic resin solutions for use in preliminary laboratory evaluations is offered by Centro Research Laboratories, Inc., in a 4-page bulletin. (4)

Heat Resistance of Standard Alloys. An interesting article on the influence of minor elements on the heat resistance of standard alloys is offered by Cerium Metals Corp. in a 16-page brochure. (5)

Molded Plastics. A variety of molded plastics products produced either by compression, transfer or injection molding are described and illustrated in a 4-page bulletin issued by Consolidated Molded Products Corp. The plants' facilities are also discussed. (6)

Plastics. Typical applications of Durez phenolic molding compounds, industrial resins and protective coating resins are profusely illustrated and described in an 8-page bulletin published by Durez Plastics & Chemicals, Inc. (7)

Blind Rivets. Complete data on Rivnuts, the only one-piece blind fasteners that serve as blind rivets, nut plates for attachment, or both, are presented by B. F. Goodrich Co. in a 40-page, illustrated booklet, No. 7197-NS. (8)

Metal Working Service. The facilities and ability of a contract service offered by L. F. Grammes & Sons, Inc., for any kind of metal working problem, whether stamping, drawing, plating, anodizing, etc., are described and illustrated in an 8-page bulletin. (9)

Spinning of Metals. The facilities of the Gray Manufacturing Co. for producing metal spinnings, including new magnesium techniques, and a variety of its products, are described in a 4-page, illustrated bulletin. (9-A)

Perforated Metals, Etc. A complete line of perforated metal products, screens, and fabricated metals is presented by Hendrick Mfg. Co. in a 128-page, illustrated catalog. A number of useful tables are included. (10)

Handling Caustics Without Corrosion. Comparative corrosion test data on refinery equipment handling caustics are presented by International Nickel Co., Inc., in an 8-page, illustrated bulletin, No. 55C. (11)

Cemented Carbides. A complete line of cemented carbide products produced by Kennametal, Inc., such as drills, saws, cutters, tool blanks, etc., is described and illustrated in a 64-page catalog, No. 47. Specifications and prices are included. (12)

Steel Plates. Complete data on sheets and sheared or flame-cut plates are presented in a 12-page, illustrated bulletin issued by Lukens Steel Co. Specifications are included. (13)

Steel Plates. E-Z-Cut plates, a special type of high manganese, high sulfur analysis steel plate for applications involving machining, such as plastic or rubber molds, jigs, fixtures, etc., are discussed in an 8-page, illustrated bulletin offered by Joseph T. Ryerson & Son, Inc. (14)

Phenolic Resins. A complete line of protective coatings, abrasive products, friction materials, etc., and their recommended uses, is discussed by Varcum Chemical Corp. in their 4-page bulletin, No. 46-1. (15)

Steel Castings. The large facilities of the Vulcan Iron Works for producing carbon- and alloy-steel castings up to 40,000 lb. in weight are profusely illustrated and described in an 8-page bulletin, No. A-423. (16)

Methods and Equipment

Electric Salt Bath Furnaces. A complete line of Hultgren electric salt bath furnaces produced by the Ajax Electric Co., Inc., is described and illustrated in a 72-page catalog, No. 116. Specifications and typical applications are included. (17)

Arc Welding Electrodes. Technical data and specifications on a complete line of Weld-Arc electrodes for the welding of mild steels and low alloy-tensile steels are presented in an 8-page, illustrated bulletin, No. 1-47-10Mp, offered by Alloy Rods Co. (18)

Protective Coating. Technical Service Data Sheet No. 7-16-100-2, four pages, discusses Alodine, the chemicals used in a rapid nonelectrolytic process to produce a protective, skin-like coating on aluminum and its alloys, offered by American Chemical Paint Co. (19)

Silver Brazing Alloys. The American Platinum Works offers a 4-page, illustrated bulletin describing their low temperature silver brazing alloys for joining steel, copper, brass, Monel, etc. (20)

Welding Malleable Iron. Instructions on how to weld malleable iron, featuring the use of Ampco-Trode coated aluminum bronze electrodes and Phostrode shielded arc phosphor bronze electrodes, are issued by Ampco Metal, Inc., in a 2-page procedure sheet. (21)

Metal Cleaners. Complete data on three basic types of metal cleaners, and the problems confronted in individual cleaning jobs, are presented by F. E. Anderson Oil Co. in a 4-page, illustrated bulletin. (22)

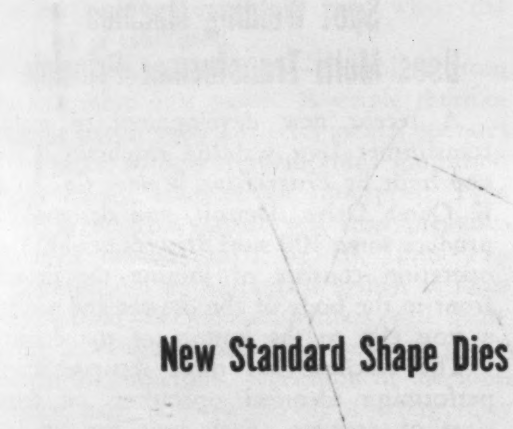
Cold Strip Mills. Small Sendzimir ZR-15 and ZR-16 self-contained reversing cold strip mills are described and illustrated in a 4-page bulletin offered by Armzen Co. Specifications, applications and a strip coil weight chart are included. (23)

Molding Presses. A variety of high-speed compression molding presses and high-speed universal plunger molding presses for producing molded plastics and soft rubber products are profusely illustrated and described in a 16-page bulletin, No. 251, published by Baldwin Locomotive Works. Specifications are included. (24)

New Materials and Equipment

New Standard Shape Dies Have Larger Bell Opening

To allow greater latitude in the angle at which stock may enter the dies, to permit faster die finishing and servicing, and to provide more lubrication of both dies and stock, *Carboloy Co., Inc.,* Detroit, has placed on the market a new line of standard square and hexagonal shape dies that have larger bell openings than previously. The dies are so designed that they may be finished to cover a range in hole sizes from 5/32 to 1⅝ in: for the square dies and from 5/32 to 1⅞ in. for the hexagonal dies.



A tungsten carbide square die, one of the new line of standard shape dies.

The enlarged bell opening in the new dies permits the stock to enter the die carrying a heavier coating of lubricant than was possible with previous dies. The enlarged bell also reduces the amount of extraneous stock which must be removed from the entering angles of the die when making up a finished die from the rough shaped die. In addition, the design of the new dies allows readier access to the internal die contours, which materially adds to the ease and quickness with which the dies may be finished and serviced.

The new dies are known as Series "D," and replace the former "R" line of Carboloy shape dies.

Powder-Metals Press Achieves 30 Strokes Per Min.

For compacting a wide range of powdered metals parts, the *F. J. Stokes Machine Co.,* Philadelphia 20, is offering a cam type press of 40-ton capacity, to operate at speeds up to 30 strokes per min.

This press is a fully automatic, cam operated machine in which independent cams control the synchronized movements of both upper and lower punches. It is equipped with a compound lower punch designed to operate either as a secondary lower punch or as a movable core rod. If desired, this mechanism can be locked in place to serve as a stationary core rod. The die table can take the full pressure applied by the upper punch, which is useful in the manufacture of shouldered bushings or similar pieces.

The upper punch is timed to stay out of the way during more than 110 deg. of the cycle before descending rapidly and then slowly compressing the metal powder in a controlled manner. This feature facilitates the feeding of difficult materials, and is essential in making parts with thin walls in which feeding is a particularly difficult problem.

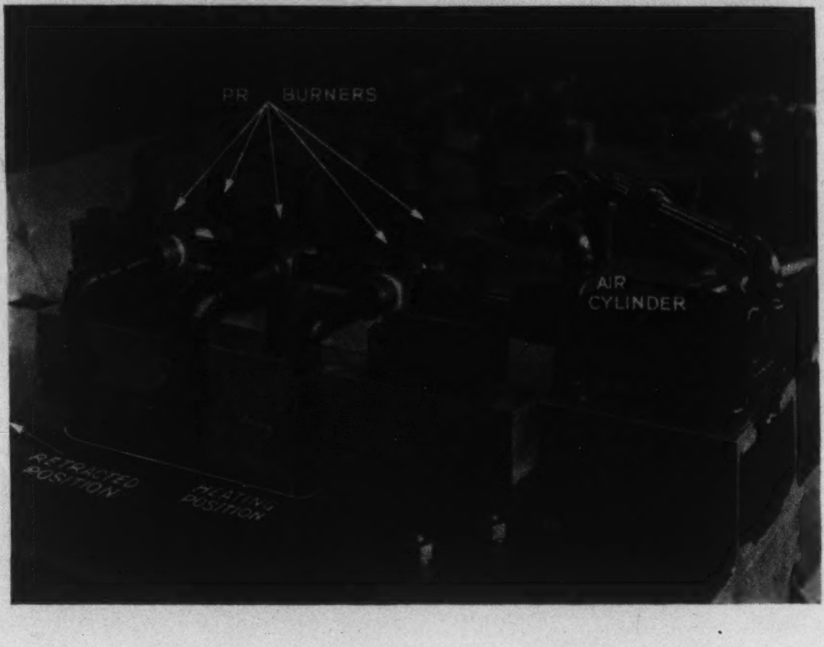
The maximum die fill is 6¼ in. and the maximum dia. of piece that can be pressed is 3 in. Alignment of the press is close, within 0.001 in. in the several planes involved. Built into the press is a lever-operated combined clutch and brake which speeds up set-up time, as well as instantly starting or stopping the machine.

Equipped with variable speed drive, production rates are from 10 to 30 pieces per min., depending upon material and size and intricacy of the piece. The machine weighs approximately 12,000 lb., complete with variable speed drive and 7½-hp. motor.

Uniform Joints Obtained On Automatic Brazing Machine

Stronger and more uniform joints are said to be obtained by automatic control of heat-pattern and heat-time, fuel supply and assembly pressure, in a new brazing machine engineered and manufactured by the *Selas Corp. of America,* Philadelphia 34. Designed specifically for a brass sink fixture, the machine completes the brazing operation within 30 sec. Three stations are provided for operation in a loading, heating and cooling sequence.

The five component parts with alloy rings preplaced are fluxed and positioned in a supporting jig. Air pressure is applied to assure close contact of all parts during the heating and cooling cycles. As the burners are brought to brazing position a solenoid valve opens the gas-air mixture line to "full on." A timer releases burners at the end of the heating cycle, to a retracted position, and cuts fuel supply to maintain a pilot condition.



Illustrated here is one station of the new Selas brazing machine.

Instrument Detects Faulty Bonding In Laminated Materials

A new instrument for detecting faulty bonding of flat, laminated materials such as plywood, veneers, metal-plastic "sandwiches," and laminated plastics, is announced by the *American Instrument Co.* of Silver Spring, Md. Known as Bondimeter it is a useful instrument for research, production testing, and inspection. It detects faulty bonding and its location, and also indicates the laminations between which the fault exists.

The device consists of a hollow aluminum cylinder with a transparent plastic window at the top and an open bottom, forming an inverted cup. Mounted inside the aluminum cylinder is a dial gage with its stem centrally located with respect to the open end of the cylinder, and resting against the surface of the test specimen.

A valve in the top of the cup automatically maintains a constant difference between the pressure inside and the pressure outside the cup. The valve has four pressure steps to accommodate bonds of different strengths and layers of different stiffnesses and thicknesses.

In operation, the Bondimeter is placed on the surface of the specimen, and the air from within the cup is evacuated by an aspirator, forming a vacuum which forces the test specimen into the cup. This pressure acts on the entire thickness of a well-bonded, laminated material and causes only slight inward deflection, as shown on the dial gage.

In the case of a faulty bonding, however, air trapped between the laminations forces the laminations apart and into the cup. This normally results in a large deflection, which is indicative of poor bonding. A comparison of the deflections obtained on opposite sides of the test specimen indicates the laminations between which the faulty bonding exists. The Bondimeter does not destroy well-bonded specimens.

Bench Induction Heater Is Space Saver

A new 2-kw. bench model induction heating unit is in production at *Scientific Electric Div., "S" Corrugated Quenched Gap Co.,* Garfield, N. J. This can be used on a shop bench, being only 22 in. wide, 20 in. high (over-all) and 16 in. deep.

The unit is simple to use and operates from a 110-v. line. It comes complete with foot switch and one work coil made to customers' requirements. This work coil can be from ½ to 2½ in. in dia., and the unit will operate with a coil of one turn to a maximum of 20 turns.

New Hardness Machine for Light and Heavy Load Testing

A new heavy load hardness testing machine, recommended for light and heavy load testing, applying loads of from 25 to 50,000 grams, has been announced by the *Wilson Mechanical Instrument Co., Inc.,* 230 Park Ave., New York 17. This model, known as Model LR, contains the refinements developed for testing with either the Knoop or 136-deg. diamond pyramid indenter (Vickers type).

Features include a fast speed elevating screw for adjustment to specimen thickness; a meter giving operator assurance the load is being applied to the indenter and indicating when the electronic tube is in operating condition and when the test cycle has been completed.

The Knoop Indicator is used for tests from 25 grams to 3600 or 5000 grams. The 136-deg. diamond pyramid indenter is used for tests from 25 to 50,000 grams. Loads of 10,000 grams are furnished as standard equipment.

Spot Welding Machine Uses Multi-Transformer Principle

A recent new development in multi-transformer spot welding machines is the one built by *Progressive Welder Co.,* 3050 E. Outer Drive, Detroit, and designed to produce some 300 steel drawers per hr. The operation consists of joining the drawer front to the body of the drawer and adding a stop clip to the bottom of the drawer.

The machine has three separate units, performing identical operations on three sizes of drawers. Each unit has six 14-Kva. transformers, each transformer taking care of two welds in series. Depending on power available, all guns in one unit can weld simultaneously; or half of the guns can weld simultaneously, followed immediately by the other half; or guns can weld in pairs, one pair after the other.

In operation, the operator loads the drawer parts in place on the fixture and pushes a button. Automatic air clamps hold the parts in place. An air cylinder then automatically rolls the fixture into welding position. All guns come down together under hydraulic welding pressure. Welding current goes on automatically. When the welding cycle is completed, guns raise automatically, and the fixture rolls out into loading position. Machine control is through an automatic sequencing panel.

● A new air setting refractory cement, called Armstrong's Air Set, is being marketed by the *Armstrong Cork Co.* It is designed for use as a bonding mortar with fire brick and insulating fire brick. It can also be used as a protective facing for fire brick or insulating fire brick furnace linings.

Vacuum Unit for Coating with Evaporated Metal Films

A new medium-size vacuum evaporator has been developed by *National Research Corp.*, Boston 15, Mass., for the preparation of evaporated metal films, the deposition of magnesium fluoride on optics, and for other applications requiring low-pressure bell jar equipment.

Embodying a continuously operating, 6-in., high-speed diffusion pump and a combined roughing and backing pump, the unit has pumping capacity for fast cycles and for handling large amounts of outgassing from materials being coated. The diffusion pump is backed by a small mechanical pump during the roughing cycle. Some idea of the speed of the unit may be gathered from the fact that a dry-air pressure of 5 by 10^{-6} mm. Hg. can be attained after 9 min. from atmospheric pressures on a clean, empty 18-in. glass bell jar.

Included with the standard machine are two sets of filament posts; a 110-v. power supply for resistance heaters or other uses; a high-capacity, high-voltage discharge unit; and a bellows turning mechanism. A vacuum safety switch located in the base plate is incorporated in the high voltage discharge circuit. This insures that the high voltage can be turned on only while the bell jar is evacuated.

The vacuum gages are controlled from a removable unit panel. A single thermocouple circuit with a selector switch operates two gages, while a non-amplified ionization gage circuit controls an untrapped Type 507 gage. This circuit will read pressures from 5 microns to 1 by 10^{-5} mm. Hg. However, on an untrapped system it must be realized that contaminations will probably prevent the gage from reading below about 0.15 microns. Operation of the ionization gage is protected by a safety relay which prevents energizing the filament unless its power supply has been reset to zero.

Bell jars can be either of the standard Pyrex, 18-in. dia. type or of a larger, 24-in. dia., all-steel construction for greater coating capacity. The latter type has two sight ports for viewing the work while in process.

● An aluminum solder that needs no flux and has good anti-corrosive and flowing properties is announced by the *Aluminum Solder Co. of Ohio,* 1360 W. Third St., Cleveland. It is applied at below 700 F, and comes in the form of rods 3/16-in. dia. and 12 in. long. With this new solder various grades of aluminum, from 2S up to 61S, have been soldered successfully. In a butt soldering job on 2S aluminum, a tensile strength of 10,000 psi. resulted, compared with 13,000 psi. for the parent metal. The maker claims that preparation for soldering is simple, such as preheating and treatment with a wire brush and a first coat of the same solder used in final operations.

New Phenolic Resin Coating Impervious to Heat

A phenol-formaldehyde protective coating, known as Phenoglaze, manufactured in England for use on all types of wood and metal products, is now available to fabricators in this country through *Phenoglaze Sales Corp.*, 315 Broadway, New York 7.

This plastic film is impervious to heat, moisture, and chemical action from salt, gasoline, oil, alcohol, turpentine, acetone, and other corrosive agents.

Phenoglaze is applied by spray, brush, or dipping. It comes as a clear coating and also in colors. It is air-drying and cold setting. Its high resistance to galvanic influences, to acids and alkaline solutions, makes it suitable for such products as furniture, station wagon bodies, wood or steel boats and radio cabinets.

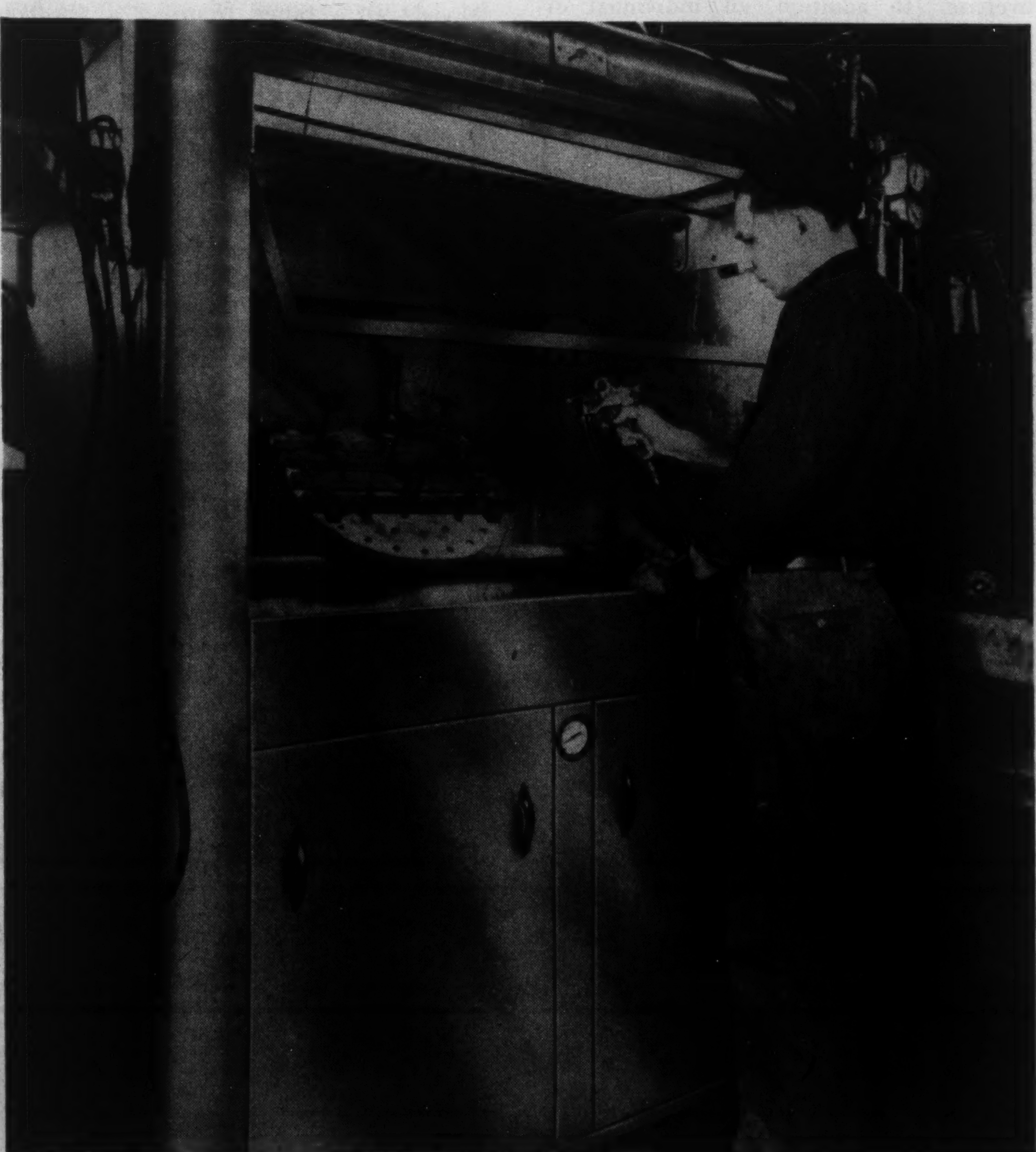
Spray Booth Designed for Silver Spraying

A new stainless steel spray booth which serves as a complete production unit for silver spraying objects in preparation for electroplating has been developed by the *Monomelt Co., Inc.,* 1611 N. E. Polk St., Minneapolis, Minn.

The unit is adapted to silver spraying plastic jewelry, plaster of Paris and plastic figurines, composition toys, glass trays and dishes, wooden novelties, etc.

The booth is equipped with foot-operated water spray, air reducer, plate glass baffle to protect operator, air pressure indicator, safety valve, and a rotating jig for holding objects to be sprayed. A powerful suction fan draws excess spray out of the booth through a duct directly behind the jig.

Constructed of stainless steel, the spray booth is impervious to chemicals that corrode ordinary metals.



The stainless steel spray booth in use for spraying plastic perfume caps before electroplating.

New Gages and Measuring Devices Control Product Accuracy

Inspection and testing operations are being increasingly applied right in the production line. This trend has created a demand for a variety of new gaging and measuring instruments. Below are described a few of these recently introduced.

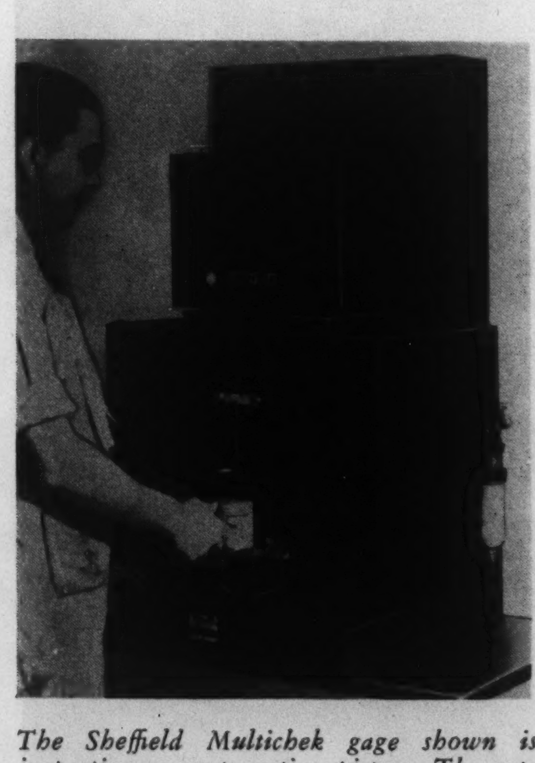
Automatic Gage

Inspections of numerous critical dimensions of automotive pistons as well as eight classifications are combined into one operation on the gaging machine developed by the *Sheffield Corp.* of Dayton 1, Ohio. Segregation into classifications is made possible by color stamping during the gaging cycle. The rate of inspection and selection is between 500 and 700 pistons per hr.

Pistons with undersize pin holes will not enter gaging position, and so are rejected at the start of the gaging operation. When the piston is in gaging position, simultaneous check is made of average diameter of pin holes at each of two bearings, diameters of four ring grooves, widths of five ring grooves, and diameter of bottom skirt.

In addition, three classifications of pistons are automatically made on the basis of the average diameter of the pin hole, selections being made in steps of 0.0001 in. between minimum and maximum tolerance limits.

The diameter of the four ring grooves are also checked; ring groove widths are checked with go and no-go gaging members, which actuate microswitches. Each dimension has its own set of red and green signal lights to show, respectively, undersize and oversize. In addition, all individual dimension circuits are integrated into one master light circuit.

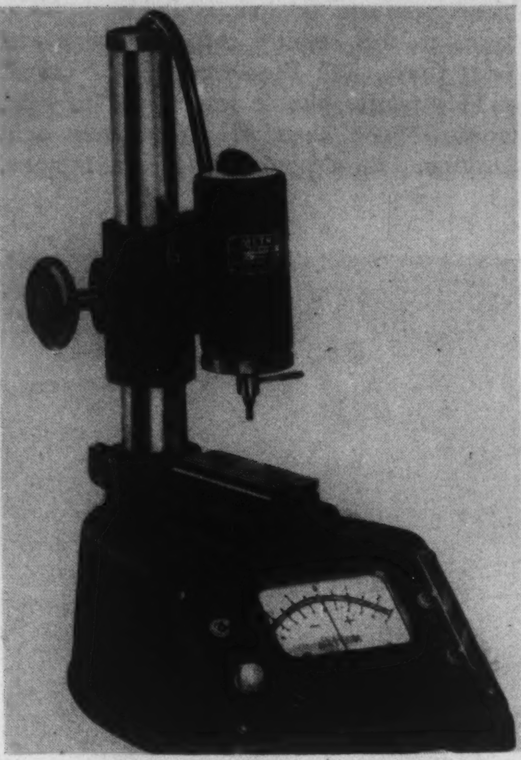


The Sheffield Multichek gage shown is inspecting an automotive piston. The rate of inspection is between 500 and 700 per hr.

Four-Range Comparator Gage

A new electromagnetic type comparator gage is now available from *Metron Instrument Co.*, 436 Lincoln St., Denver 9, Col. Each gage has four ranges of magnification (selected by means of range switches) so that a single gage is suitable for a wide range of gaging applications from checking gage blocks to production inspection of machined parts.

Three models are available calibrated in either English or metric units. Model 10 has a gaging range from 1-millionth in. to 4 ten-thousandths in.; Model 20, a range from 10-millionths in. to 5-thousandths in.; Model 30, a range from ½ a ten-thousandths in. to 20-thousandths in. The spindle pressure is adjustable and calibrated from 4 oz. to 2½ lb., and the head can be rotated at any angle about the column or in the vertical plane for versatile application.



This Metron comparator gage has four ranges of magnification.

The head can be removed for special setups if desired. The gage has only two moving parts: the spindle, which is supported in flexure, and the pointer, which is mounted on jewel pivots.

Self-Centralizing Hole Gage

A self-centralizing indicator gage which shows size in tenths of thousandths, in the inspection of I.D.'s between 0.250 and 0.500 in., has been announced by *Federal Products Corp.*, 1144 Eddy St., Providence, R. I. The spring-centralizing design plus the precise measuring contacts and motion transfer units locate themselves in the hole and show the true diameter reading.

The gage employs 14 interchangeable extensions to cover the range from ¼ to ½ in. It explores any hole within its capacity to a maximum depth of 2¼ in., revealing diameter and also roundness, taper, bellmouth, and other hole inaccuracies.

This gage, known as Model 1204, can be used as a single-purpose inspection tool or for checking a large variety of sizes. Being a point-to-point contact gage, it reveals any small area imperfections in the hole.

Direct Reading Inside Micrometer

A new type of inside micrometer, called the Rimat, has been announced by the *Richards Machine Tool Co.*, 124 S. Isabel St., Glendale 5, Calif. This tool measures internal dimensions and is useful when machining back of a flange or boring recesses that have to be kept to close limits. In such instances, the tool can be inserted, the measurement taken, the measuring pins retracted, and the tool withdrawn.

The ends of the measuring pins are hardened and ground on a radius for accuracy and to prevent cramping. All wearing surfaces are hardened and ground. Means are provided so that all wearing surfaces can be adjusted.

The micrometer has a range of 1 in. and is available in two sizes; the 3 to 4-in. size with extra measuring rods up to 6 in.; and the 6-in. size with extra measuring rods up to 12 in.

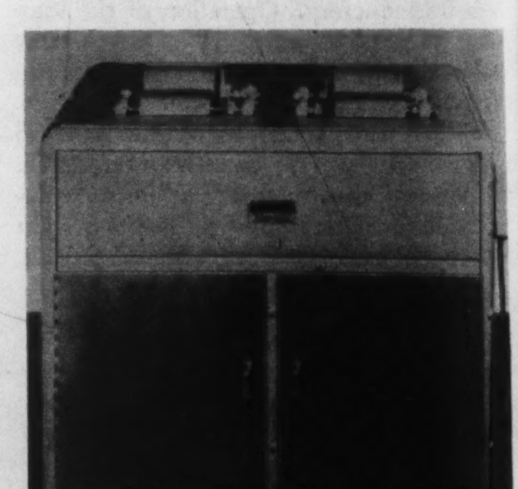
Outside Micrometers

The new micrometers manufactured by the *Tubular Micrometer Co.*, St. James, Minn., unlike conventional solid frame micrometers, are of tubular construction. This design is said to cut the structural weight up to 50%.

The micrometers are furnished in a variety of types for numerous precision measuring requirements. These include the conventional type micrometer ranging in size from 0 to 24 in.; the blade type tubular micrometer for measuring narrow depths is furnished in sizes from 0 to 4½ in.; roller mill tubular micrometers may be had with a 3-in. or 6-in. throat depth. A line of bow type micrometers with interchangeable mandrels is manufactured in sizes from 0 to 96 in.

Rough and Finish Lapping Performed on Same Machine

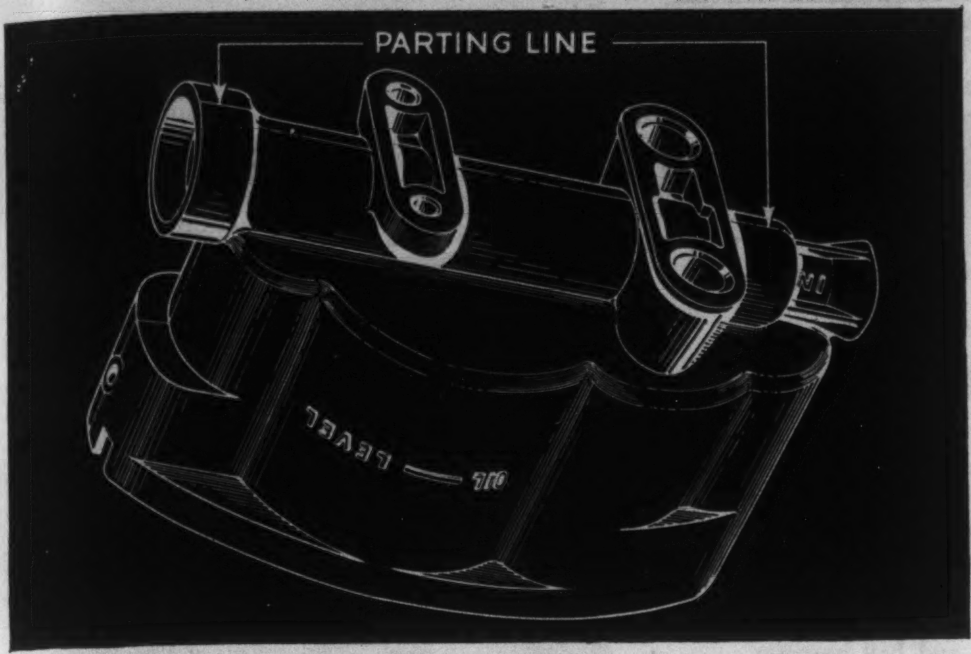
A two-stage lapping machine for high precision small cylindrical parts has been designed by *Size Control Co., Div. of American Gage & Machine Co.*, 2500 Washington Blvd., Chicago 12. On this machine both rough and fine, or finished, lapping operations can be performed. On the left hand roll, rough lapping is accomplished, and on the right hand roll finished lapping.



A centerless lapping machine for small cylindrical parts that can perform both rough and finish lapping.

Lapping time is said to be greatly reduced, and a precision finish of less than 2 micro in. is obtainable. With the equipment a large number of parts can be lapped without making set-ups, ring laps or other tools, as in conventional methods of lapping.

PRACTICAL CONSIDERATIONS IN DIE CASTING DESIGN



UNDERCUTS—WHEN TO USE AND WHEN TO AVOID THEM

In designing die castings, undercuts (recesses in casting walls which interfere with ejection from the die) should be avoided, if possible, since they entail the added cost of movable die cores. Where undercuts cannot be avoided, however, the designer will profit from early consultation with the die caster to arrive at the most economical means of production.

The above zinc alloy die cast oil reservoir is a good case in point. By casting this piece with the parting line through the axis of the tube at the bottom, the recesses next to the tube are formed by fixed portions of the die. Although movable cores are still required (to form the interior of the casting, the tube openings and the holes and recesses in the base flanges) there are such compensating advantages as uniformly thin wall sections and overall weight reduction. Furthermore, this method of production permits engraved lettering on the side walls of the casting.

Shown below is a zinc alloy die cast fitting in which one undercut was eliminated through die design and another was obtained with economy by subsequent machining. Ordinarily the recess between the two longitudinal ribs (see photograph at the left) would be regarded as an undercut. By parting the casting in the plane of its axis, however, this recess (and another on the reverse side of the casting) is formed by fixed projections in each half of the die. This method of parting also makes it possible to cast the external thread which is later chased. There is, however, an annular groove inside the flange on this casting (see photograph at the right) which does constitute an undercut. It would be possible to form this groove with "knockout" cores in the die but, since this would greatly retard casting speed and probably necessitate some machining, the piece is chucked and the entire groove is machined from the solid.

ALLOY SELECTION

Equally important to the design of a die casting is the selection of the proper alloy for its production. The zinc alloys used in the die casting industry conform to specifications of the American Society For Testing Materials and the Society of Automotive Engineers (see table below). When a casting is properly designed and the alloy composition is carefully controlled with respect to every element involved, outstanding mechanical properties and dimensional stability will be assured in zinc alloy die castings.

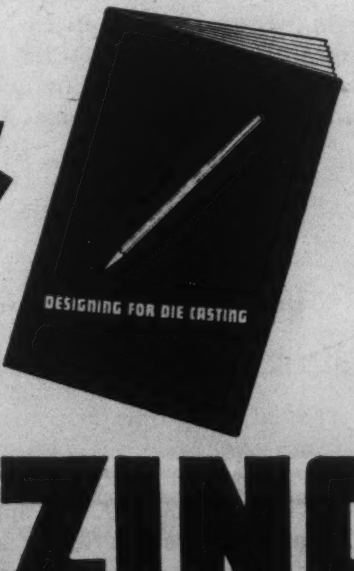
Zamak* and Corresponding A.S.T.M. and S.A.E. Alloys

	A.S.T.M.	S.A.E.
Zamak-3	XXIII	903
Zamak-5	XXV	925

*A trade mark (registered in the U. S. Patent Office) identifying the zinc alloys developed by The New Jersey Zinc Company and used in the die casting industry.

For additional data on die casting design ask us—or your die casting source—for a copy of the booklet "Designing For Die Casting".

Send for your copy



ZINC
FOR DIE CASTING ALLOYS

The New Jersey Zinc Company, 160 Front St., New York 7, N. Y.

The Research was done, the Alloys were developed, and most Die Castings are based on
HORSE HEAD SPECIAL (99.99 + % Uniform Quality) ZINC

Plastic Dip Coating Builds ¼-in. Thickness in Single Dip

A new method for protecting process equipment such as pipe, valves, fans and rotors and other intricately shaped equipment has been announced by the *U. S. Stoneware Co.*, Akron, Ohio. A new liquid has been developed consisting of 100% solids and containing no volatiles such as water, thinners, solvents, reducers, etc.

This compound, known as Tygoflex, is corrosion resistant and can be used for protecting process equipment.

The new compound, known as Tygoflex, when applied by the usual techniques of dipping, spraying, brushing, etc., and subsequently subjected to heat for a short period, converts to a thick, protective insulator resembling in appearance a glossy black rubber compound of medium hardness.

The compound can be applied to any surface or material which will withstand the time and temperature involved in the fusion, such as metals, ceramics, glass, and heat-resistant plastics such as Duralon. Thicknesses ranging from 1/16 to ¼ in. can be built up in a single dip.

The compound is resistant to all mineral acids, dilute or concentrated, alkalies, salts, oxidizing agents, and a limited range of solvents. Its upper-temperature limits are substantially above that of the other Tygon plastics, ranging up to as high as 250 F.

New Material Prepares Aluminum Alloys for Painting

A material, known as Prepaint, is available from the *Technical Processes Div., Colonial Alloys Co.*, Ridge Ave. & Crawford St., Philadelphia 29, for applying to aluminum and its alloys which are to be painted or lacquered in high production.

The material is applied at room temperature by dip, spray or brush; it reacts chemically and bonds with the aluminum surfaces in from 15 to 60 sec. in a single chemical treatment. It is stable, nonflammable, and nontoxic.

A typical procedure for a production line is: Remove grease, dirt and foreign material; immerse in Prepaint solution at room temperature for from 15 to 60 sec.; rinse and dry; spray, dip or otherwise apply a good type of paint or lacquer.

Wrought, cast, die cast, machined, forged, extruded and other forms of aluminum and its alloys respond to this treatment. Aluminum parts with inserts or attachments of other metals or plastics can be treated to form a good bond with paint or lacquer. Aluminum finished with this material may be painted immediately after drying, or the work may be held over for subsequent painting.

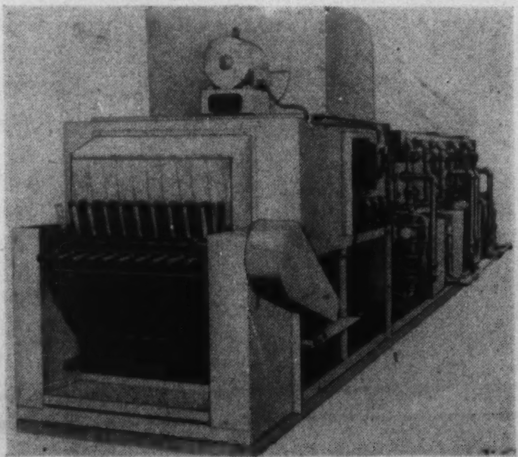
● A new light weight self-contained surface comparator made by the *Photron Instrument Co.*, 5713 Euclid Ave., Cleveland 3, Ohio, is now available for 100% surface inspection of machined parts. The comparator can be used on flat and round work, odd shape pieces such as cams, thread flanks and ball bearings.

Washing Machine Cleans Metal Parts Prior to Plating

A new flat conveyor type washing machine for cleaning and processing of metal parts prior to plating has been introduced by *Optimus Equipment Co.*, 267 Church St., Matawan, N. J. The new machine handles a sequence of related operations in seven simple consecutive stages: hot alkali wash, hot water rinse, warm cyanide wash, cold rinse to sewer, hot rinse, dry.

The operation takes metal parts directly from processes, such as polishing and feeds directly to the plating machine. The two hot rinses are hooked in sequence, thus affecting a further operating saving. Conveyor can also be built with flight bars for baskets and individual pieces, or with a mesh belt for any type of parts in bulk, or individual pieces.

Overall size of machine is 35 ft. in length, 6 ft. in width, and 7 ft. in height. This machine is designed with a belt speed of 4 ft. per min. for a production in excess of 100 parts per min. Machine can be adapted to a wide range of speeds and types of treatment.



Discharge and dryer end of the Optimus flat conveyor type metal washing machine.

Bench Type Butt Welder Has Clamping Air Block

A new bench type butt welder by *Banner Products Co.*, 4951 N. 29th St., Milwaukee 9, Wis., has eight ranges of heat. The unit is manufactured for either 220- or 440-v., 60 cycle current. It includes a 2-in. dia. air block for clamping, and maintains a constant pressure on material being welded.

The head on this butt welder is of high strength bronze and water cooled.

Operation is started by a covered foot switch connected to a 4-way Solenoid air valve which brings clamps to position. The movable platen has left hand lever with pilot switch connection which closes to apply current at the joint. At the same time the hand lever is pulled toward stationary platen for upset. Current is automatically shut off by an adjustable limit switch.

New Knee-and-Column Milling Machine Announced

A new addition to their line of knee-and-column type milling machines has been announced by the *Cincinnati Milling Machine Co.*, Cincinnati 9. Designated the No. 2 ML., it is offered in plain and universal styles.

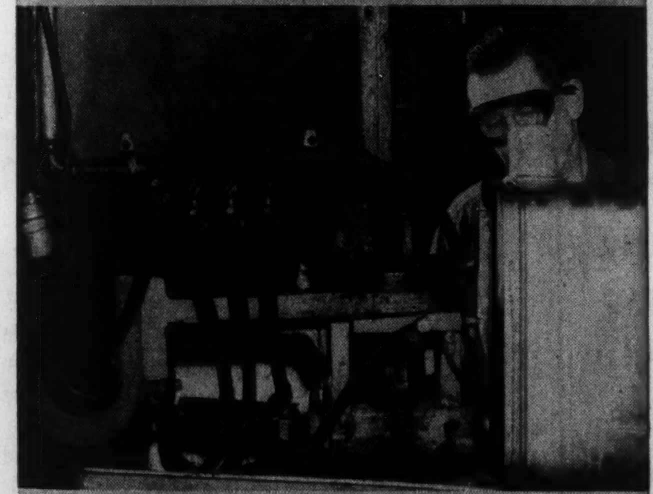
The machine has speed and feed ratios 60 to 1 and 120 to 1, respectively. There are 16 spindle speeds, ranging from 25 to 150 rpm., changed with a single crank type control at the side of the column. The crank operates a hydraulic selector valve, while the actual work of shifting gears is performed hydraulically.

Feed rates are changed in the same manner as the speeds—one-half turn of a single crank type control, throughout the complete range of 16 feeds, from ¼ to 30 in. per min.

The spindle runs on three precision bearings; tapered roller at front and center, and a ball bearing at the rear. The rear bearing is not constrained endwise, to allow for changes in length of the spindle caused by the effects of heat and the pull of the draw-in bolt.

Welding 44½″ pressure tight seam

Spot-welding baffles inside tank



Ends are assembled with 102″ of pressure tight seams

White Saves 30% — Improves Gas Tanks

...by Resistance Welding

When the White Motor Company switched to resistance welding in the fabrication of gasoline tanks for its motor trucks, White found that the tanks were not only stronger and more leak-proof, but also cost 30% less as they came to the assembly line.

Only 4 Progressive machines were required by White to take care of its production requirement of 100 complete tanks per shift. With the savings made, these machines—two spot welders and two seam welders—should pay for themselves in less than six months.

That's the kind of job resistance welding is doing all over. Sometimes the savings are a little less—sometimes even greater, depending on the nature of the job.

But—you cannot afford today not to investigate how much money you can save in production by switching to resistance welding. Progressive's Process Engineering Department will be glad to work with you in figuring the type of process, any minor changes in design, type of equipment needed, and potential savings.

In the meantime, are you receiving the "Welding Pictorial" published monthly by Progressive to acquaint industry with the latest methods and machines?

These 4 machines improved the quality of White gasoline tanks yet cut cost 30%.

CABLE ADDRESS "PROGWELD"

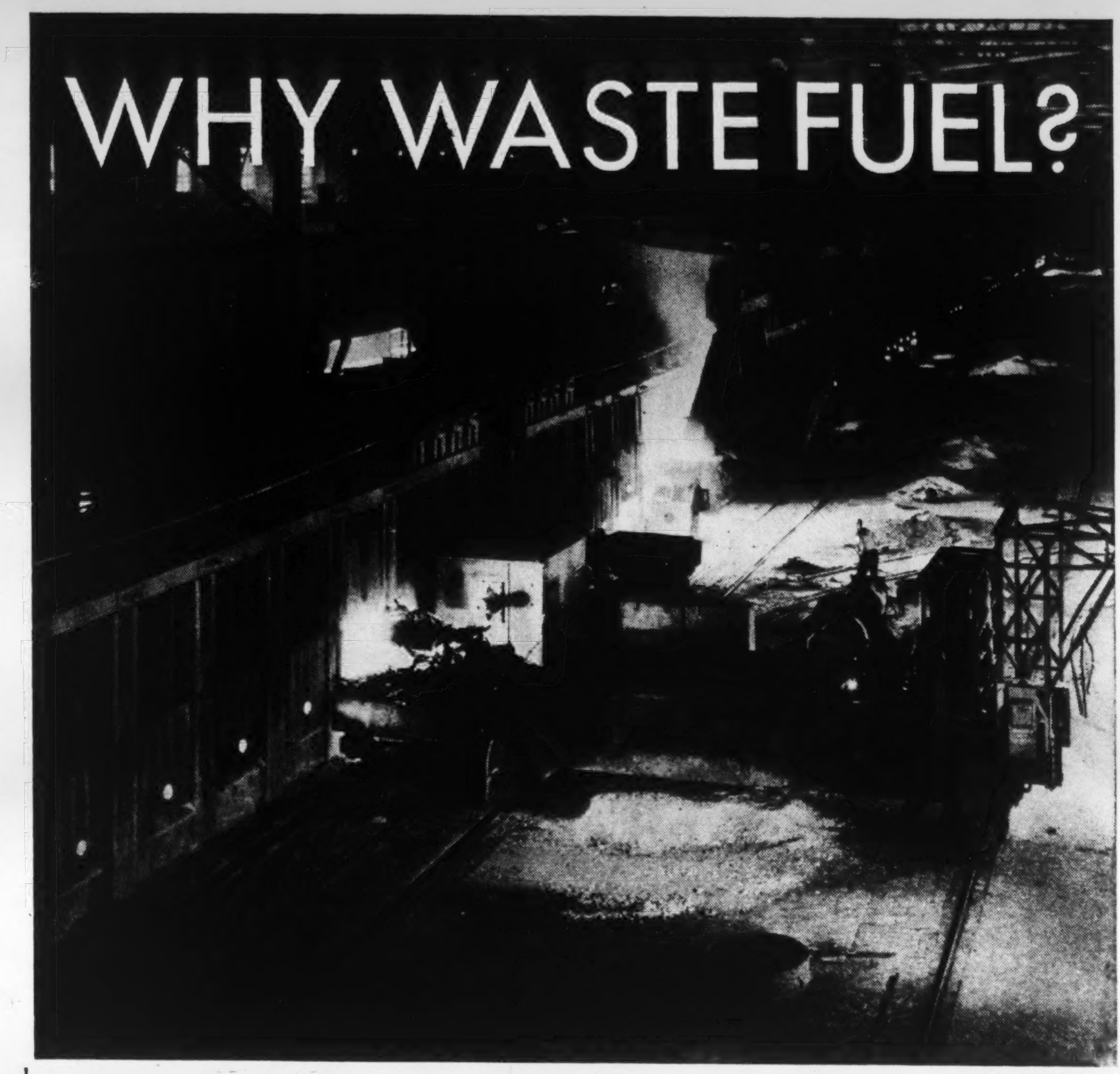
6

MEMBER
RWMA

IT PAYS TO WELD

PROGRESSIVE Welder Co. 3050 E. OUTER DRIVE • DETROIT 12

RESISTANCE WELDING EQUIPMENT



Therm-O-flake *prevents waste*
BY REDUCING HEAT LOSSES...

MORE THAN 25% of Open Hearth fuel can be wasted through heat lost through brickwork and heat absorbed by cold infiltered air.

Therm-O-flake INSULATIONS are designed to reduce heat losses and seal furnace walls against cold air infiltration. These are used regularly on hundreds of open hearth furnaces and save steel producers thousands of fuel dollars daily.

Therm-O-flake ENGINEERS will prepare an accurate fuel economy survey of existing furnaces in your plant and submit complete thermal data and recommendations for safe maximum insulation of any open hearth furnace, on request.

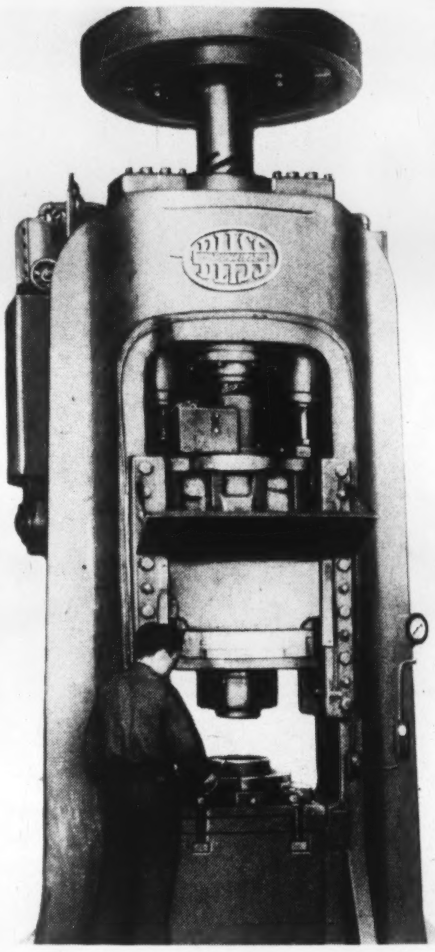
Illinois Clay Products Company
JOLIET, ILLINOIS

Exclusive Manufacturers of
Therm-O-flake
open hearth Insulation

Hot Forging Press Uses Hydro-Screw Principle

A new percussion press design, which introduces hydraulic pressure for moving the slide, and which is applicable to production of hot forgings of steel, brass and aluminum, has been developed by the *E. W. Bliss Co.*, Detroit 2.

The operating principle of this 600-ton Hydro-Screw Press employs a flywheel at the top of the screw which is brought up to speed by hydraulic pressure and utilizes the accumulated energy developed to deliver a quick, hammerlike blow, uniform in power. On a 16-in. stroke under maximum power, the machine cycle is completed within 3 sec., start-to-return.



The 600-ton hydro-screw press shown here is something new in percussion press design.

Power is adjustable and can be reduced by regulating the delivery of the variable delivery pumps. Continuous lubrication of the screw is maintained by means of a pump in the slide which provides a constant supply of oil at the top of the nut while the press is in operation.

For immediate reversal at rebound, the quick action valves reverse the motion of the hydraulic pistons. At the top position, the valves immediately lock the hydraulic pressure, preventing the slide or gate from drifting down.

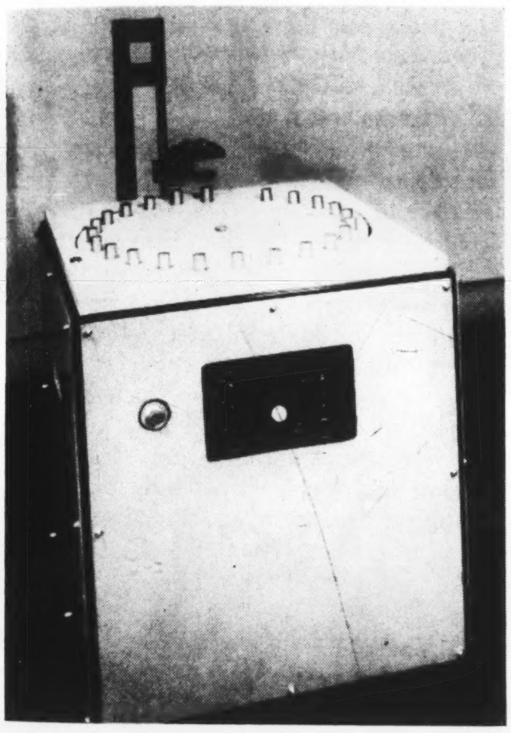
For die setting, a push button control with selector switch is provided. During inching, the slide can be brought up or down in small increments. An air operated lift-out in the bed and similar knock-out in the slide are controlled by limit switches operated by the slide. This type of press is available in three sizes: 400-ton, 600-ton, and 1,000-ton capacity.

Indexing Table for Induction Heating Small Parts

A new indexing table, to be used for soldering, brazing and annealing of round or irregularly-shaped small parts, has been announced by *Lepel High Frequency Laboratories, Inc.*, 39 W. 60th St., New York 23. This unit has been developed particularly for heating of parts where shape or control of heat requires closer or more accurate coupling than can be achieved by moving the parts through a tunnel-type coil.

Parts on the table are moved or indexed into heating position, the load coil lowers to surround the part, and the heating cycle is carried out, all automatically. Length of the heating cycle can be varied to meet requirements by an adjustable timer, and the index speed adjusted by changes in the variable speed drive. Upward and downward travel of the load coil is normally 3½ in., but can be changed to meet requirements.

The new table can be used in conjunction with any Lepel high-frequency converter or other high-frequency generator, and comes equipped with a built-in automatic timer which controls the heating time of the part. This automatic timer also controls the power of the converter, turning it on and off simultaneously with the downward and upward stroke of the load coil.



This indexing table for induction soldering, brazing and annealing moves the parts through the heating cycle automatically.

● A new heavy duty overhand buffer, especially adapted to long and deep work requiring maximum clearance, is in production by the *Bradford Machine Tool Co.*, Cincinnati 4, Ohio. Known as Model 660, the buffer is belt driven by ball bearing motor. Motor platform is adjustable for belt tension, and design permits drive belts to be changed without removing housing from shaft.

PRODUCTION UNINTERRUPTED . . . when THERMALLOY

SECTIONAL HEARTHS are INSTALLED

TO EXPAND AND NOT BUCKLE
is the result of
PROPER DESIGN

Correct metallurgical balance and proper design are the prime features of this THERMALLOY sectional hearth. Heat and corrosion resistant, it retains its shape under elevated temperature changes and gives longer service than the conventional one piece type.

Thermal stress due to expansion and contraction is confined to smaller individual sectional areas, thus warping and cracking is minimized

For longer service life, specify THERMALLOY X-RAY controlled castings.

AMSCO ALLOY and THERMALLOY are identical.

MUFFLES BASKETS
RETORTS CHAIN
POTS FLEX BOXES
FURNACE PARTS

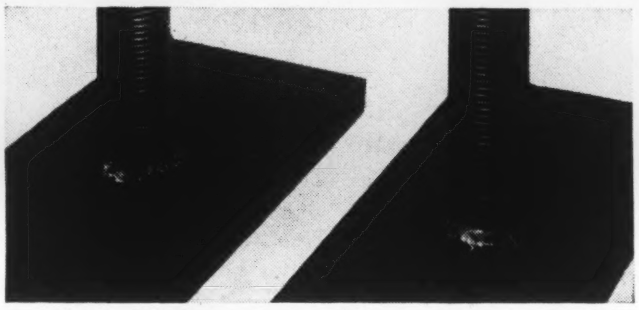
AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO.

New Electrode Simplifies Tough-to-weld Jobs

"SHIELD-ARC LH-70" is a new heavily coated electrode designed primarily for the welding of steels of poor weldability. Its as-welded properties are 75,000 to 80,000 lbs. per sq. inch and 25% to 30% elongation in 2″. Stress relieved tensile strength is 70,000 lbs. per sq. in. minimum. Normally it produces a convex bead.



Welds made in high-sulphur steel. Left: Made with mild steel electrode. Right: Made with new "Shield-Arc LH-70" Electrode.

TYPICAL APPLICATIONS. Experience to date shows that this electrode produces exceptional results in these applications:

- Low alloy high tensile steels which cannot be preheated.
- High sulphur (free machining) steels.
- High carbon, medium carbon steels.
- High silicon electrical sheet steel.
- For welds to be porcelain-enameled without annealing.

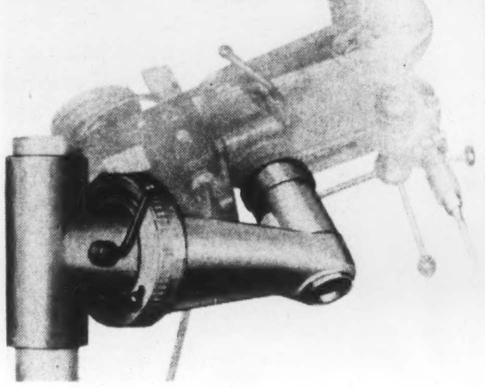
PROCEDURE. Use DC—electrode positive, work negative. Hold a short arc. ⅛″ and 5/32″ may be used for vertical and overhead positions, single or multiple pass. Make vertical welds from bottom upward. Make overhead welds with stringer beads or narrow lateral weave.

For further details, call the Lincoln Welding Engineer nearby or write The Lincoln Electric Co., Dept. 242, Cleveland 1, Ohio.

Butt welding medium carbon (.50% C) steel sprocket teeth forgings with the new Lincoln "Shield-Arc LH-70" Electrode.

Attachment Converts Standard Drill Press into Radial Drilling Machine

The development of an all angle radial arm to be mounted on standard 2-, 2¼-, 2½- or 2¾-in. column drill presses has been announced by the *Empire Foundry & Machine Corp.*, Ashland, Ky. It eliminates the necessity of a tilting or universal table for drilling holes at any desired angle and most any radius. The arm increases chuck-to-column capacity by 16 in., and auxiliary column increases chuck-to-base capacity 5 in.



By using this all angle radial arm, drilling with a standard drill press from almost any angle is possible.

The radial arm is clamped firmly to the base collar by bolts through a degree table graduated through 90 deg. (45 deg. right to 45 deg. left). Base collar is equipped with a coordinate clamp lock with ball handle that releases or tightens two clamping wedges simultaneously. It simplifies raising or lowering drill head and permits swinging drill head and radial arm.

Die Casting Machine Capable of 720 Shots Per Hour

A new self-contained, die casting machine manufactured by *Robert A. Cox Co.* is being distributed by the *Ermac Co.,* 1426 S. Santa Fe Ave., Los Angeles 21, Calif. This medium sized, "Goose-neck" type machine is air operated and measures 22 in. by 72 in. and 40 in. high.

The holding pot has a capacity of 300 lb. of zinc alloy; it is cast of Meehanite iron. A 4½-in. lining of fire brick insulation is a feature of the furnace itself. A safety vent is also provided to take care of any metal which might get into the furnace by accident.

The machine is equipped with a loose type removable nozzle, and a removable bar facilitates die loading. All working parts are accessible for inspection, adjustment or maintenance. The size of the die plates is 16 in. by 16 in., making the die capacity 11 in. by 16 in. The casting capacity is 1½ lb., and the number of shots per hr., 720 max.

Correction

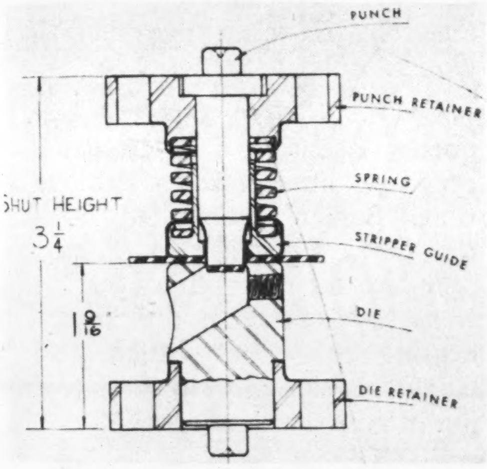
The correct address of *Air-Hydraulics, Inc.*, is 401 Broadway, New York 13. It was given incorrectly as 410 Broadway in the March issue.

Interchangeable Die Sets for Small Press Equipment

A new line of low shut height (3¼ in.) interchangeable self-stripping punch and die units for small press equipment has just been placed on the market by *Raar Mfg. Co.*, 1663 N. Highland, Los Angeles 28, Calif.

The units feature low shut height, air slug ejection, closer hole centers, simplicity of construction, and wide range of hole sizes (1/32 to 1 1/32 in.).

Change or replacement of the punch and die units is readily accomplished because stripper and stripper guide are removable by a half turn. Punch may be removed from retainers with a light pressure, and changes may be accomplished without disturbing the set-up.



Cross section drawing shows essential parts of the punch and die unit.

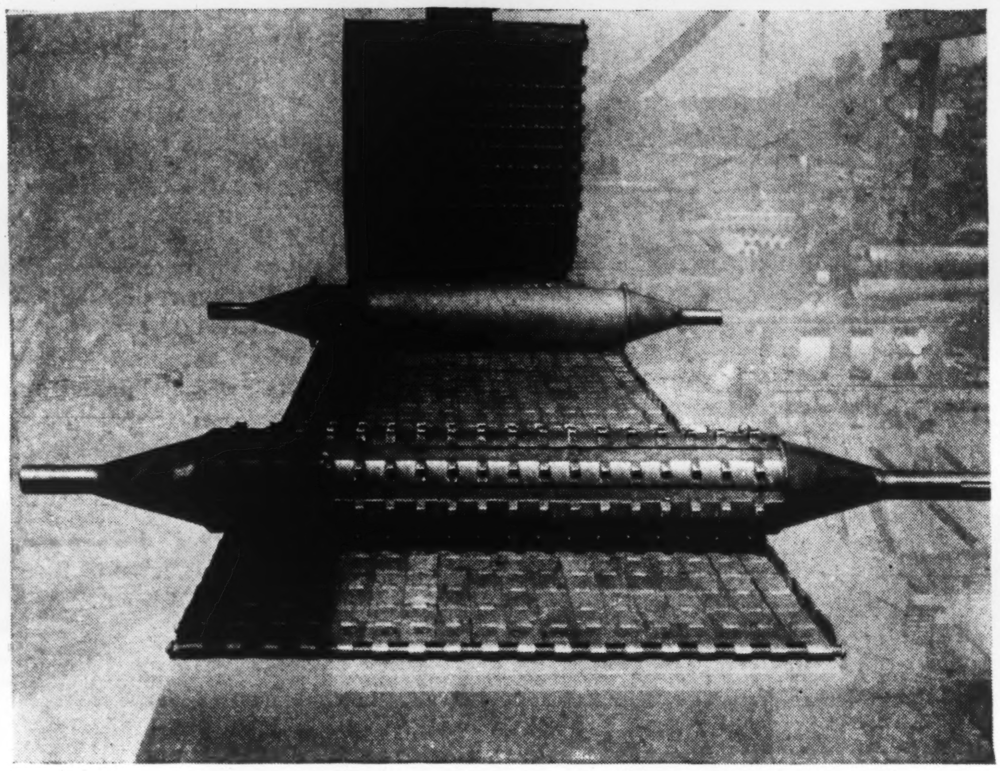
Without retainer, the stepped die construction and height in conjunction with standard die steels is especially designed for use in cut-off, notching, blanking and other press operations. The die may be rotated in relation to the mounting holes to provide clearance for the slug ejector opening.

- A new cutting fluid has been announced by the *Penetone Co.*, Tenafly, N. J. This product is a liquid concentrate, non-inflammable and non-toxic, which is diluted with approximately 15 parts of water for use as a cutting fluid. With the use of this liquid emulsifier, the cutting fluid actually cleans the metal as it lubricates and cools. The new liquid contains no solvents, abrasives, or free alkali, and cannot harm the hands.

DURALOY

HERE'S ONE OF OUR MORE DIFFICULT JOBS

DURASPUN



It's a conveyor assembly for a heat-treating furnace, alloyed and cast for a large manufacturer of automobile parts. Perhaps you would be interested in some facts:

Alloying Elements . . 15% Chromium, 35% Nickel
Conveyor Belt . . . . 8,400 pounds, statically cast
Head Shaft . . . . . . 1,625 pounds, centrifugally cast
Tail Shaft . . . . 804 pounds, centrifugally cast

The belt consists of several thousand individual links assembled and held together by alloy steel rods. No machining of the links was necessary. The lugs on the head shaft were cast integrally with the shaft. The end cones on both shafts were cast statically and then welded on.

You may not need a conveyor for a heat-treating furnace such as this, but if you need *any* high alloy casting—for resisting heat, corrosion or abrasion—we would like to discuss producing it for you. Our experience in static castings goes back to 1922 and in centrifugal castings back to 1931, both pioneering dates.

THE DURALOY COMPANY

Office and Plant Scottdale, Pa. • *Eastern Office* 12 East 41st Street, New York 17, N. Y.

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5-DU-1

Cooked to order

As you know, a cupola can be charged with materials to produce the type of castings desired — that is, if the metallurgist understands what materials to specify.

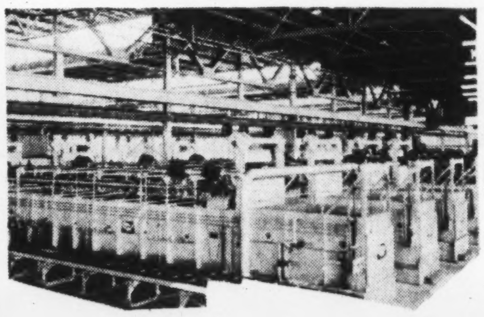
We can give *Strenes Metal* a considerable range of characteristics by certain changes in the formula. This affords unusual flexibility in adapting *Strenes Metal* castings to the work they are required to do.

So, if you need a special hardening quality in a die, we can give it to you with *Strenes Metal;* or we can give you what you need in machinability, or toughness, or any reasonable combination of properties.

This is one of the reasons why more and more manufacturers of metal products are using *Strenes Metal* dies. If you're interested, we'll be glad to answer your questions.

Strenes Metal
DRAWING AND FORMING DIES

THE ADVANCE FOUNDRY COMPANY
100 PARNELL STREET · DAYTON 3, OHIO



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Intercontinental S. A. Buenos Aires

News of... ENGINEERS COMPANIES SOCIETIES

Engineers

Kenneth L. Walker has been made vice president in charge of production, Kalamazoo Stove & Furnace Co. Since 1940 he has been head of his own company in Detroit serving as consulting engineer. Here he directed plant layout, material processing, cost systems, wage and incentive systems, production control, job evaluation, job methods, time studies and design styling.

C. P. Doherty, employee with Despatch Oven Co. for 27 years, has become factory manager, while *G. L. Schuster* has been named chief engineer.

Dr. P. J. Selgin, expert in high frequency radiation and electronics, has been appointed to the staff of the National Bureau of Standards, Washington, D. C. He will work on electronic ordnance for the military services. He was graduated from the Royal Engineering School of Milan, and has taught physics and electrical engineering in American colleges.

Dr. Melville F. Peters, in charge of research at Titeflex, Inc., Newark, N. J., has been appointed chief engineer. Up to 1943 he was a principal physicist at the Bureau of Standards, where he worked on aircraft ignition, resulting in 70 patents. He received his doctor's degree from Johns Hopkins University in 1931.

Lyndon C. Cole has been appointed chief engineer, machine division, Osborn Mfg. Co., Cleveland, and will have charge of engineering and design of foundry equipment. Previous similar connections have been with Cleveland Automatic Machinery Co. and Hydraulic Press Mfg. Co.

Lambert R. Pistoles has been made production engineer, All American Aviation, Inc., manufacturing division, having previously been in charge of method engineering for du Pont. Other positions have been project engineer, and tool and die design engineer with Curtis Wright and Packard Motor companies. He attended the University of Rome, Italy.

M. I. Signer, head of the department of mining, is the new dean of the faculty of the Colorado School of Mines. He is a member of the American Institute of Mining and Metallurgical Engineers and several other societies.

Fred A. Maser has become superintendent, Shippensburg, Pa., plant, SKF Industries, Inc. He joined SKF in 1927 as an apprentice tool, die and gage maker, and for the last several years has been a general foreman in the tool-making department.

Leo A. Carter, for 16 years with Douglas Aircraft Co.'s engineering and manufacturing division, has been made manager of the parent plant at Santa Monica, Calif. He has degrees in structural and aeronautical engineering.

Charles S. Redding, president, Leeds & Northrup Co., makers of electrical measuring instruments and heat-treating furnaces, has received the honorary degree of Doctor of Science from the University of Pennsylvania.

Emmett A. Williams has been named vice president in charge of operations, National Bearing Div., American Brake Shoe Co., and *I. E. Cox* becomes vice president in charge of engineering. Mr. Williams has been works manager since 1942 while Mr. Cox started as research engineer.

D. S. Harder has resigned as chairman of the board, E. W. Bliss Co., because of his complete occupation with his duties as vice president in charge of operations, Ford Motor Co.

Dr. George H. Spencer-Strong, director of research, Pemco Corp. since 1942, has been elected a vice president. He has perfected many new developments in scientific porcelain enamel procedure and has written innumerable articles, books and papers on the subject. He perfected 16 basic oxides from which over 400 colors for porcelain enamel can be matched and mixed. He has been very active in technical society affairs.

Otis Hutchins has retired as technical director, Carborundum Co. after 35 years of high standing in the field of electrochemistry and electrometallurgy. He is succeeded by *Harry C. Martin,* assistant technical director. *George J. Easter,* formerly director of

Certain . . . Speedy

COLEMAN SPECTROPHOTOMETER
FOR PRECISE COLORIMETRIC DETERMINATIONS

Today Colorimetric methods research has demonstrated the chemist's need for a VERSATILE instrument.

There are no restrictions on the light band, wave length, that may be used . . . while filter photometers are limited to the colored glass filters available.

Coleman Spectrophotometers have slit width sufficiently narrow, so that definite, SHARPLY defined wave lengths are isolated.

The UNIVERSAL is a combination Spectrophotometer, Photo-Nephelometer and Fluormeter . . . the Junior is a direct reading Spectrophotometer.

TURNING ONE KNOB
permits selection of precise light band required.

Free Exact nephelometric procedures for calcium from 0 to 3 ppm. and colorimetric technics for magnesium, silica, nitrate nitrogen, etc. ALSO . . . for Steel Analysis, the combined method . . . one gram sample . . . for F, Mo, Ni and Cr has proved most satisfactory. This procedure is also available for the asking!

Plugs Into 110 Volt AC Line

MM 5-47

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Parts with intricate contours in quantities from 500 to 5 million!

Complicated parts . . . intricate shapes . . . precision non-ferrous castings . . . are made to EXACT specifications by the CHEMICAST process.

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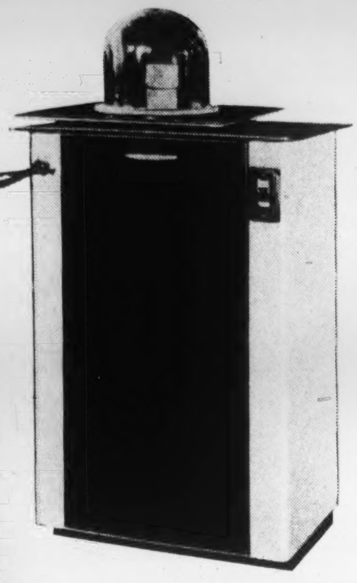

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The KERR VACUMATIC

is your answer!

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the solution to the bottleneck created by old-style, low-vacuum pumps. This unit will evacuate a bell jar 8" x 5" in about five seconds — to a vacuum of 29.6" (about 3 times as high a vacuum as 29.0").

The "Vacumatic" consists of a motor (¼ to 2 hp.), Nitralloy pump, and piping and valving details, all efficiently mounted in an attractive black and grey steel cabinet. The 18" x 18" joggle plate will accommodate bell jars up to 16" in diameter.

Available with either one or two vacuum stations, A.C. or D.C., in any desired line voltage.

See the **KERR VACUMATIC** in our new catalog "Precision Casting by the Lost Wax Process" — 32 pages of information, equipment and "know-how". Send for your *FREE* copy today!

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Just published — The Influence of Minor Elements on the Heat Resistance of Standard Alloys. A copy of this valuable information available on request.

*CERIUM STANDARD ALLOY

Containing 45-50% Cerium. Balance principally rare earth metals

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research, becomes manager of research and development. *Henry R. Power*, chief chemist, moves up to manager of laboratories. *Fred A. Upper* becomes manager of manufacturing technical service.

Companies

Kaiser Aluminum has partially overcome the soda ash shortage by completing its own plant at Owens Lake, Inyo County, Calif. The new works will produce 100 tons of soda ash daily by the "natural" process as against the "Solvay" process.

Handy & Harman has opened up its fifth plant, this one at 3625 Medford St., Los Angeles 33. The plant will produce silver brazing alloys and fluxes, sterling silver and karat gold sheet and wire, silver anodes, sterling and fine silver grain.

A contract for complete and up-to-date rolling mill equipment for the new $130,000,000 steel plant to be erected in Sweden has been placed with the *Loewy Engineering Co.* It will turn out over 350,000 tons of rolled steel yearly, starting in 1949.

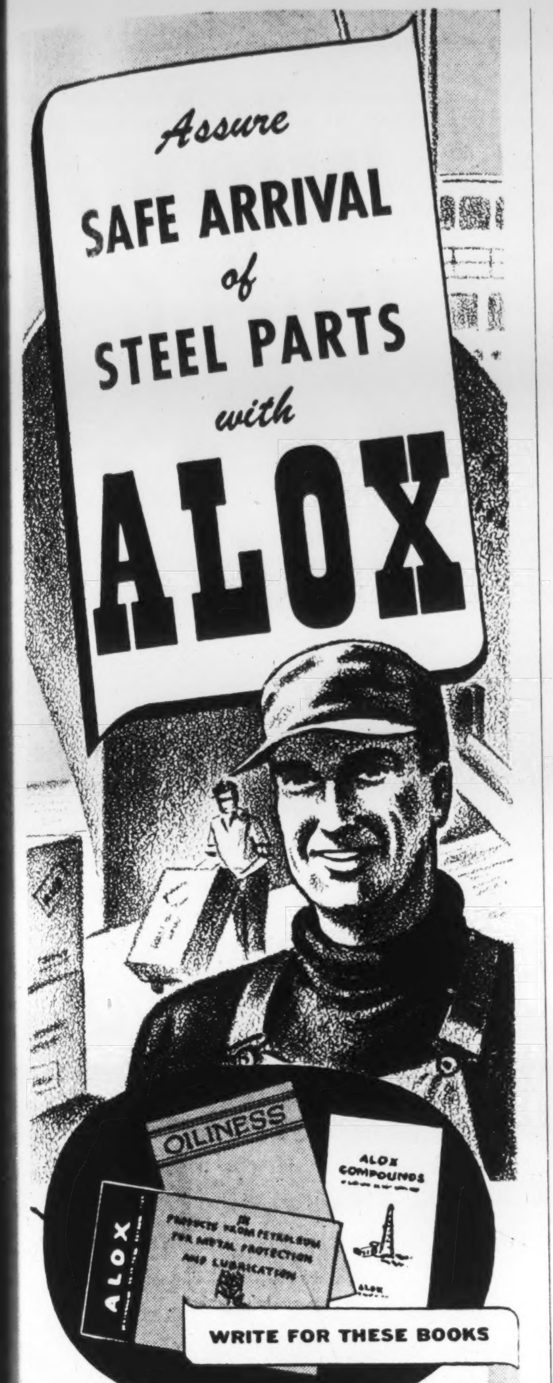
The *Barium Steel Corp.* has sold the *Jacobs Aircraft Engine Co.*, Pottstown, Pa., for $1,500,000 to A. R. Jacobs, vice president and general manager. Barium has also formed a new subsidiary, the *American Steel Tractor Corp.*

The *Carnegie-Illinois Steel Corp.* has licensed the *Inland Steel Co.* to manufacture "Cor-Ten," corrosion-resistant, high strength low alloy steel. Inland meanwhile has licensed Carnegie-Illinois to manufacture its "Hi-Steel." The *Great Lakes Steel Corp.* has licensed the *Sharon Steel Corp.* to produce its N-A-X high tensile steel and the entire range of N-A-X 9100 series low alloy steels.

The *Owens-Corning Fiberglas Corp.*, Toledo, Ohio, has purchased a 42-acre site in Santa Clara, Calif., for construction of a $7,000,000 plant, employing up to 1000 persons.

The *Aluminum Co. of America* will discontinue its operations at Niagara Falls, N. Y., before March 1, 1949, because of "higher" manufacturing costs. The plant, which produces aluminum ingots, employs 300 persons.

The *Magnaflux Corp.* held a "Magna-



RUST INHIBITORS

- Insist on the use of ALOX 388-940-707 inhibitors for the maximum protection of steel parts during fabrication, assembly, storage and shipment.

Successfully used to protect overseas shipment of war equipment during World War II. Today these film forming rust preventives containing ALOX inhibitors are used in the control of corrosion of farm and construction equipment.

Write for literature on ALOX products and where to buy the rust preventives containing ALOX

ALOX CORPORATION
3928 BUFFALO AVENUE
NIAGARA FALLS, NEW YORK

flux Weld Inspection Conference" at the Congress Hotel, Chicago, May 8 and 9. The meetings were conducted as an open forum, with discussion leaders from various fields. Fluorescent penetrant inspection as applied to inspection of welds in nonmagnetic material was also dealt with.

Noranda Mines, Ltd., Toronto, has purchased from the War Assets Corp. the *Canada Strip Mills,* Montreal East. A new company, *Noranda Copper & Brass, Ltd.,* is being formed to take over and operate the plant, which will turn out a complete line of copper and brass mill products. The *Bridgeport Brass Co.* will have a substantial minority interest.

Carnegie-Illinois Steel Corp. has effected a postwar consolidation of its metallurgical division. The metallurgical units will be under the direction of product metallurgical engineers, each of whom will have an assistant in Pittsburgh and a senior service metallurgist in the Chicago area.

American Light Alloys, Inc., 1265 McBride Ave., Little Falls, N. J., is a new nonferrous foundry specializing in production of quality aluminum and magnesium sand castings. William Wilson, Jr., formerly general superintendent, Eclipse-Pioneer Div., Bendix Aviation Corp., is president of the new company.

Wheelco Instruments Co. of Chicago, maker of electronic instruments for measurement and control of industrial processes, has arranged for manufacture and marketing of these instruments throughout the United Kingdom by *Ether, Ltd.* of Birmingham.

The completion of highly modern research laboratories and addition of new machine tool equipment to facilitate production of superchargers in the *Pesco Products Div., Borg-Warner Corp.,* in Cleveland, is announced. The air-conditioned laboratories are equipped with the most modern devices and instruments for measuring airflow and studying the aerodynamic performance of superchargers and internal combustion engines.

The *Skinner Chuck Co.,* New Britain, Conn., has purchased all physical assets of *Allied Control Valve Co., Inc.,* S. Norwalk, Conn., and will be known as the *Allied Control Valve Div., Skinner Chuck Co.*

BRICKSEAL
REFRACTORY COATING

WHEN COLD

Brickseal becomes flint hard as it cools — protects walls from damage.

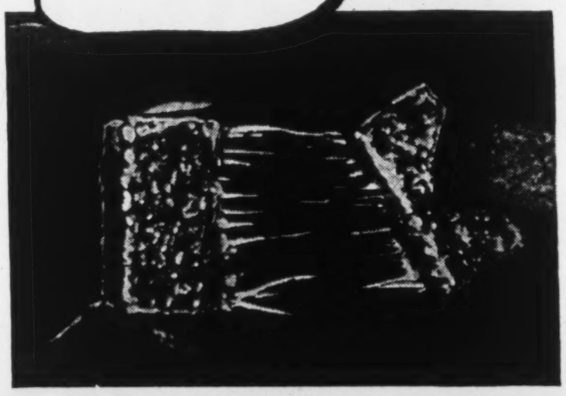
APPLIED LIKE PAINT—Brickseal, a combination of high fusion clays and metal oxides, protects refractories . . . preserves brickwork . . . prevents cracking, spalling and flame abrasion.

When heated, Brickseal deeply penetrates the pores and joints of the bricks and forms a highly glazed ceramic coating for refractory walls.

Brickseal is also used as a bonding material; it produces a tight brick-to-brick joint and welds the wall into one solid unit. Write for illustrated booklet; ask for a demonstration.

Brickseal is semi-plastic when hot allowing it to expand and contract with the furnace

SEMI-PLASTIC WHEN HOT



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THOROUGH removal of drawing lubricants is vital to economical production procedures. The incompletely removed lubricant often causes costly rejects in painting and enameling. During annealing, it is burned into surfaces to form deposits that are more difficult to remove later. Or it may result in the build-up of an insulating film on the metal, impeding production in spot- and seam-welding machines.

Your local Oakite Technical Service Representative is ready to study your lubricant-removal problems. Ask him to specify a tailored-to-fit Oakite compound to provide thoroughly clean work surfaces . . . to assure efficient, economical after-drawing operations. Oakite in-shop service is free. Specialized Oakite cleaning compounds save time, lower costs, keep production moving. So consult Oakite TODAY!

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Specialized Industrial Cleaning
MATERIALS • METHODS • SERVICE

News of...

ENGINEERS COMPANIES SOCIETIES

The *Hannifin Mfg. Co.* of Chicago has changed its corporate style to the *Hannifin Corp.* and has moved offices to 1101 S. Kilbourne Ave., Chicago.

The *Pittsburgh Lectromelt Furnace Corp.,* Pittsburgh 30, Pa., has recently completed arrangements with *Stein et Roubaix,* Paris, France, for manufacture of Lectromelt furnaces in France. Associates of Stein et Roubaix in Belgium will manufacture the furnaces for Belgium and its colonies. Arrangements have also been concluded with *General Electrica Espanola,* Bilbao, Spain, for Spanish manufacture.

The *Borg-Warner Corp.* acquired the Franklin, Pa., steel works of the *Chicago Railway Equipment Co.* on May 1.

The patents and manufacturing rights of the Sunstrand 3-wheel grinder, formerly made by the *Sunstrand Machine Tool Co.,* Rockford, Ill., have been acquired by the *LeMaire Tool & Mfg. Co.,* Dearborn, Mich.

Societies

Felix Edgar Wormser has resigned as secretary and treasurer of *Lead Industries Assn.* to become assistant to the president of the St. Joseph Lead Co., as of May 12. His successor was scheduled to have been announced at the annual meeting May 9. Mr. Wormser had occupied his trade association position for 19 years, prior to that having been an editor on a mining publication. Mr. Wormser is a leading authority on lead and one of the industry's chief spokesmen. He has authored a book on metals and minerals.

The *Acid Open Hearth Research Assn.,* Pittsburgh, proposes to conduct research on the use of oxygen in the acid open hearth furnace at one of the plants of the association. The association announces that the tonnage of acid open hearth steel melted in 1946 was 1,132,199 tons, a reduction of 20% from 1945 which, in turn, was 27% lower than in 1944.

The *American Society of Mechanical Engineers* will hold its 1947 annual meeting in Atlantic City, Dec. 1 to 5, this being the third time in its 68-year history that it has held this convention outside of New York. Headquarters will be the Chalfonte and Haddon Hall. The convention theme will be: "The

the use of AJAX PHOSPHOR-COPPER

15 STANDARD ALLOYS BY AJAX
Ajax Tombasil
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Ajax Nickel-Copper 50-50%
Ajax Manganese Copper
Ajax Aluminum Alloys
Ajax Phosphor Copper
Ajax Silicon Copper
Ajax Nickel Alloys
Ajax Phosphor Tin

Send for booklet "Ingot Metals of Today"

NOTE: * "Proper Melting Decreases Foundry Losses," contains interesting data. Also, the booklet, "Non-ferrous Ingot Metals of Today." Write for both. They are free.

Successful foundrymen deoxidize or "clean up" molten metal by a scientific method worth using as indicated:

They use phosphorus . . . expertly . . . in the form of "Ajax Phosphor Copper" . . . added as the crucible is removed from the furnace . . . for virtually all brass and bronze alloys.

In notched waffle sections, or in shot form, Ajax 15% P-Cu does its work at .01% (1 oz. per 100 lbs.). Introduced, and having time to react when stirred with a whirling motion of the skimmer, it causes oxides to rise for effective removal by skimming from the surface. It is best to avoid phosphorus build-up from back stock.*

If you use phosphorus these days, use Ajax Phosphor Copper (useful also in producing your phosphor bronze).

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AJAX METAL COMPANY PHILADELPHIA 23, PA.
ASSOCIATE COMPANIES
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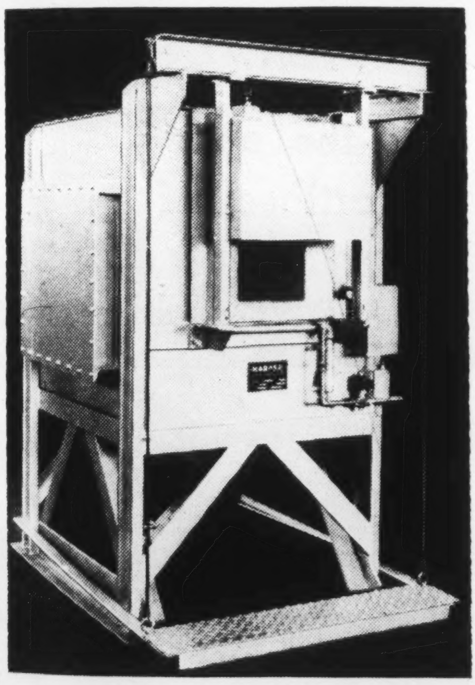
Harper

ELECTRIC FURNACES

7. Who builds Harper Electric Furnaces?

Harper Electric Furnaces are individually designed by engineers who have specialized on high temperature electric furnace construction for many years.



A thorough knowledge of the importance of correct balance between heating elements, refractories, temperature control and other requirements for uniform, accurate temperatures results in satisfactory performance. Harper Furnaces are built in a wide range of types, sizes and capacities for industrial, laboratory and school uses. Write for data.

Harper
ELECTRIC FURNACE CORPORATION
**1461 Buffalo Avenue
Niagara Falls, N. Y.**

Engineers' Responsibility in Increasing National Productivity."

The *Industrial Research Institute, Inc.,* has awarded its 1947 medal to Dr. Charles A. Thomas, vice president and technical director, Monsanto Chemical Co., for outstanding contributions to industrial research.

An advanced eight-day course in quality control by statistical methods will be conducted June 27 to July 5 at *Purdue University,* Lafayette, Ind., under leadership of I. W. Burr of Purdue. Topics will include: Background of control charts, significance of differences, analysis variance, linear and multiple correlation, etc.

Meetings and Expositions

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, annual meeting. Chicago, Ill. May 15-17, 1947.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Oil and Gas Power Division meeting. Cleveland, Ohio. May 21-24, 1947.

MID-AMERICA EXPOSITION. Cleveland, Ohio. May 22-31, 1947.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, Metals Technology Regional Conference. Boston, Mass. May 23-24, 1947.

INSTITUTE OF THE AERONAUTICAL SCIENCES, spring meeting. Detroit, Mich. May 26-27, 1947.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, aviation division meeting. Los Angeles, Calif. May 26-29, 1947.

METAL POWDER ASSOCIATION, spring meeting. New York, N. Y. May 27, 1947.

AMERICAN SOCIETY OF HEATING & VENTILATING ENGINEERS, semi-annual meeting. Coronado, Calif. June 1-4, 1947.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semi-annual meeting. Chicago, Ill. June 16-19, 1947.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Atlantic City, N. J. June 16-20, 1947.

AMERICAN ELECTROPLATERS' SOCIETY, industrial finishing exposition and annual meeting. Detroit, Mich. June 23-27, 1947.

NATIONAL ASSOCIATION OF METAL FINISHERS, annual meeting. Detroit, Mich. June 25, 1947.

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"SERVITE"
TYPE R
Thermocouple Protecting Tube

For Cyanide and Salt Baths

GORDON SERVICE

Gordon Type R tubes, made and specially treated for use with thermocouples in cyanide and salt baths, not only give greater protection by preventing detrimental gas infiltration and penetration, but also have unusually long life in service. Join the many satisfied users and lower your tube replacement costs.

This is only one item in Gordon's complete line of protecting tubes for practically every application. Over a million of them have been put in service in the past few years. No matter what your requirements in protecting tubes are, both in regular and special sizes, consult Gordon first.

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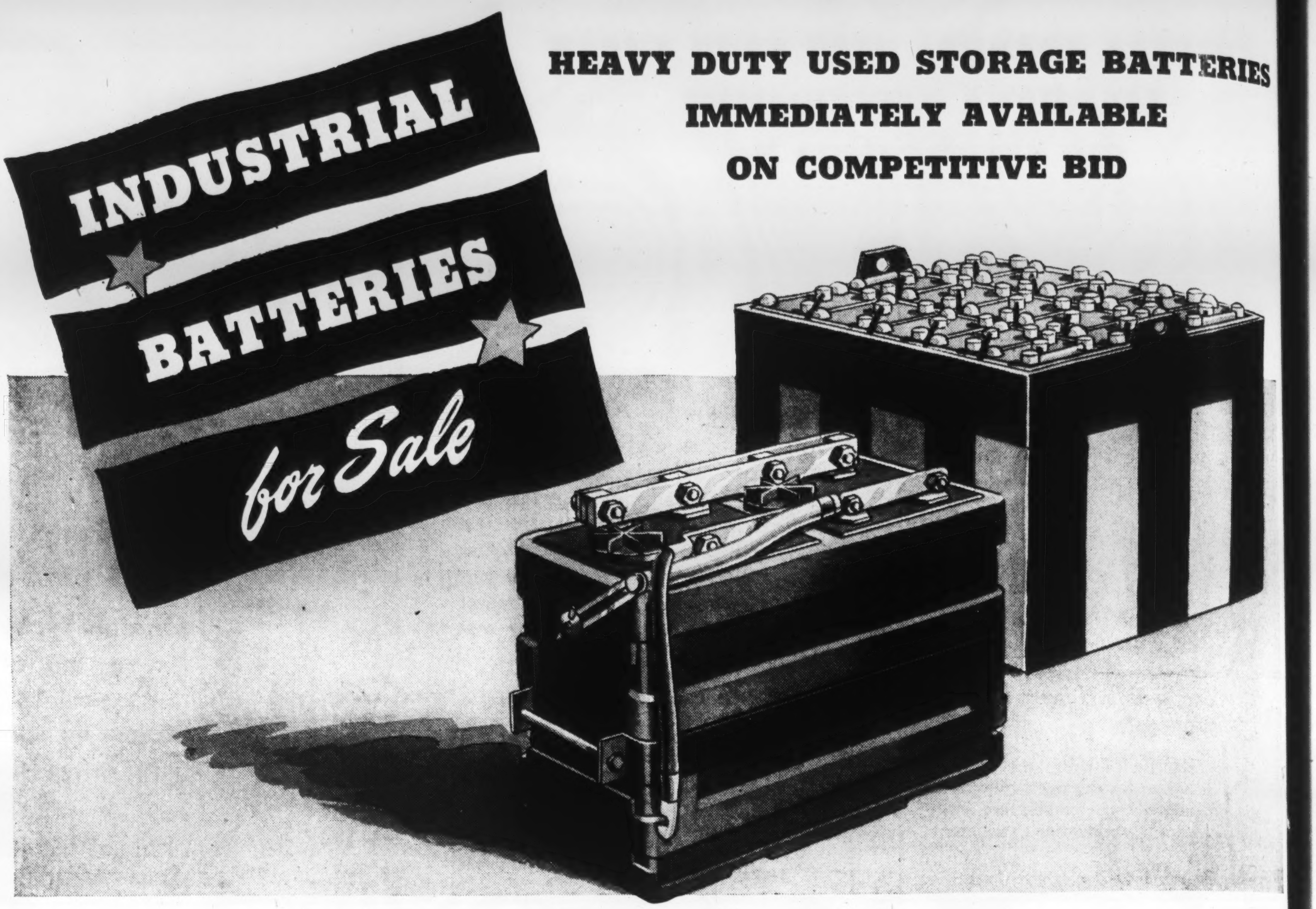

HEAVY DUTY USED STORAGE BATTERIES
IMMEDIATELY AVAILABLE
ON COMPETITIVE BID

Heavy duty batteries are still hard to get on the open market—but now many are available at WAA offices in:

CHICAGO
CINCINNATI
DENVER
PHILADELPHIA
RICHMOND

Most of these special purpose batteries are used. They're in serviceable condition and most are adaptable to a variety of jobs where low-voltage or stand-by power is needed. Made by nationally known firms, they're now being offered to enable you to make complete replacements at surprisingly low cost. Write, wire or phone now—or come in yourself to one of the offices indicated, to make sure you get the batteries you need. Also ask to have your name placed on the used battery mailing list.

Special Fixed Price Sale

Some unused batteries are also being offered at low fixed prices. To receive listings, write one of the above offices and ask to be placed on the industrial battery mailing list.

1109

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The Last WORD

by T. C. DU MOND

Travel Notes

Since much of this is being prepared between visits to a few industrial get-togethers, there is likely to be some elements of a tourist's report present. Travel is broadening, even if that effect comes only from sitting on bar stools and the edges of Pullman berths. If nothing else, I learned that there can be quite a change in weather in just a few miles. In Pittsburgh on a Saturday it was shirt-sleeve weather, but the same day in Buffalo there was snow.

Transportation Needed

To this pair of eyes, there is only one thing lacking in the new Westinghouse motor plant in Buffalo, and that is a modern internal transportation system to carry visitors around. Under one roof there is almost 1,900,000 sq. ft. of manufacturing and service area. Work being transferred to this plant is being moved from East Pittsburgh. That in itself is quite a task, but when one realizes the job is being done without losing any production, it becomes a stupendous super-colossal task. What makes the move a minor miracle is the fact that there was actually a production gain of almost 25% in March. We think Westinghouse engineers will agree that modern materials and methods had much to do with that gain. We were almost tempted to capitalize the words *materials and methods* in that last sentence, but that would have been too much like advertising our own name. Heaven forbid!

Fish and the Modern World

While visiting at Westinghouse we were reminded of one of the lesser known uses of electronics. It seems that in some streams fish are *persona non grata.* For some reason screens, dams and other barriers cannot be used. Into this breech rushed the electronic engineers who developed a fish discourager which is said to be highly efficient. The what-you-may-call-it shoots a stream of electrons into the water. The electrons are sufficiently strong to discourage the fish and chase them away without permanent harm. Next thing you know there will be an electronic fish hook which will take all the sport out of the universal pastime.

Thin Stainless Steel

One of the crying needs for high-speed aircraft as well as for planes based in or near salt water atmospheres has been an extremely thin, accurately rolled sheet of stainless steel. Part of this need will be filled with the output from the new plant of Washington Steel Corp., Washington, Pa. A new company, Washington Steel is producing stainless steel sheet in 36-in. widths and in gages from 0.078- to 0.004-in. thick. It will be rather interesting to watch this infant of the steel industry grow, since our visit there was practically at its birth as a commercial factor. This baby is rather lusty, we might add, since capacity is rated at 1,500 tons per month of sheet.

High-Speed Planes

Recently we heard Larry Bell, president of Bell Aircraft, speak on the problems of supersonic flight. Among other interesting statements Bell made was that aluminum alloy sheet would not be used for outside surfaces of such planes, since at the terrific speeds anticipated, friction would be sufficient to melt the metal. Bell predicted that stainless steel would be used. For obvious reasons, Bell is enthusiastic about helicopters and their future. He feels that this transportation medium will some day surpass the automobile. It's the only transportation method that does not require any type of subsidy to exist, says he.

Keeping Abreast of Fibers

I can't imagine why, but recently there was announced that soon there would become available sweaters made of aluminum. They might be alright for some people, but glancing at the comparative elasticity of aluminum and wool, it is doubtful that the sheep need worry about losing a friend in either Lana Turner or Jane Russell.

What Next?

Most of us realize that permanent magnets are used for many interesting jobs, but it's doubtful if one certain application has come to mind. While editing an article—to appear in our June issue—on permanent magnet materials, we were brought up short, in studying the list of products in which magnets were used, to find among the more prosaic products the listing of false teeth. Perhaps we are not too imaginative, but we can't quite see how permanent magnets fit this application. It could be that such teeth are used by people with an excess of iron in their systems. Any light on this subject will be welcomed.

More on the Snath

Those of you who saw this page in March may recall our reference to the fact that snaths are now being made of aluminum. Rather than letting well enough alone, we figuratively opened our mouth and put the usual foot in it. At least one reader who served his time swinging a snath took exception to our statement that many farmers who used one didn't know that a snath is a snath. We apologize. Smart farmers (and most of them are smart, today) know what a snath is. Our farm-spent summers apparently were not sufficient to overcome our city-bred ignorance.

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